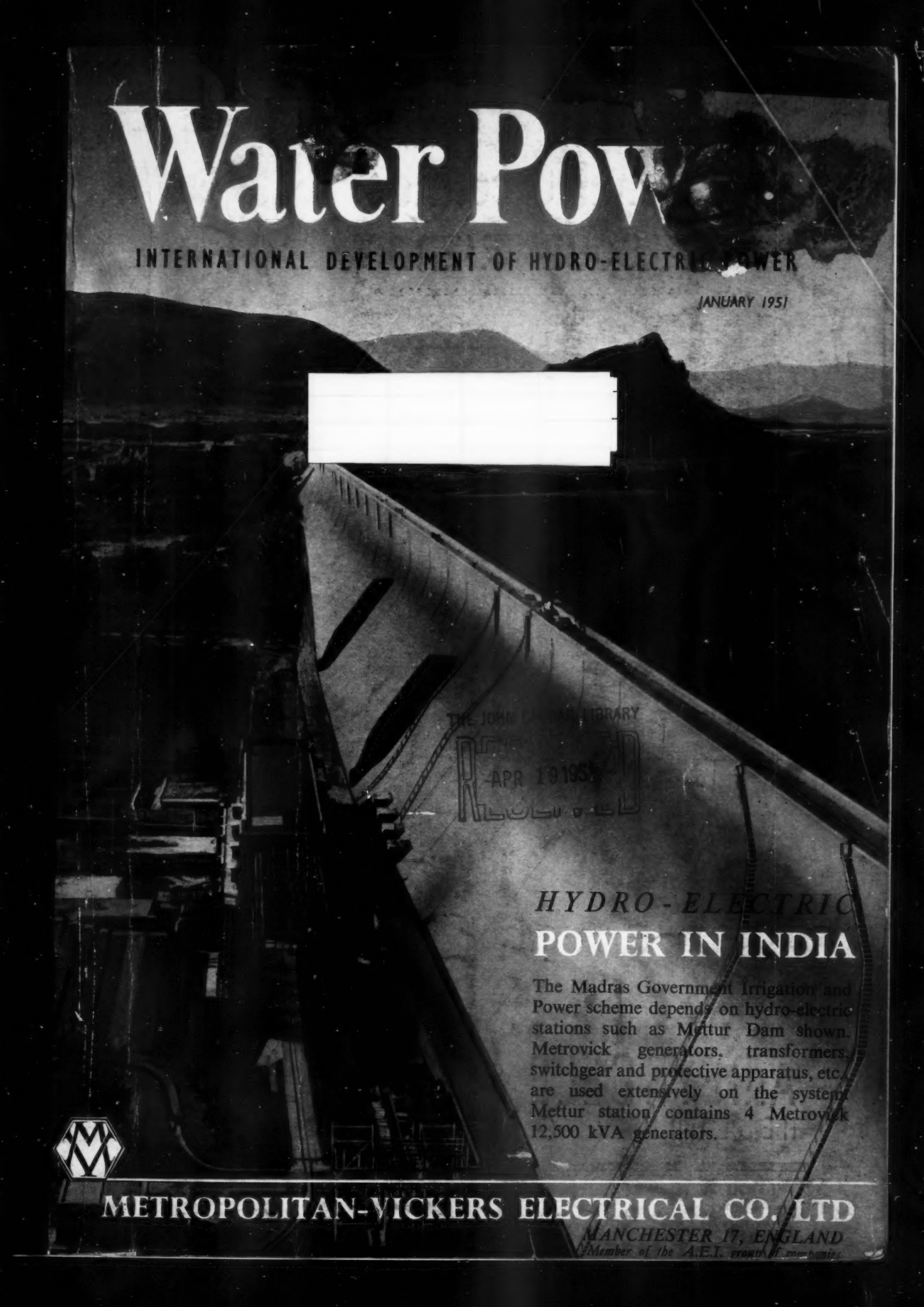
Water Pow

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

JANUARY 1951

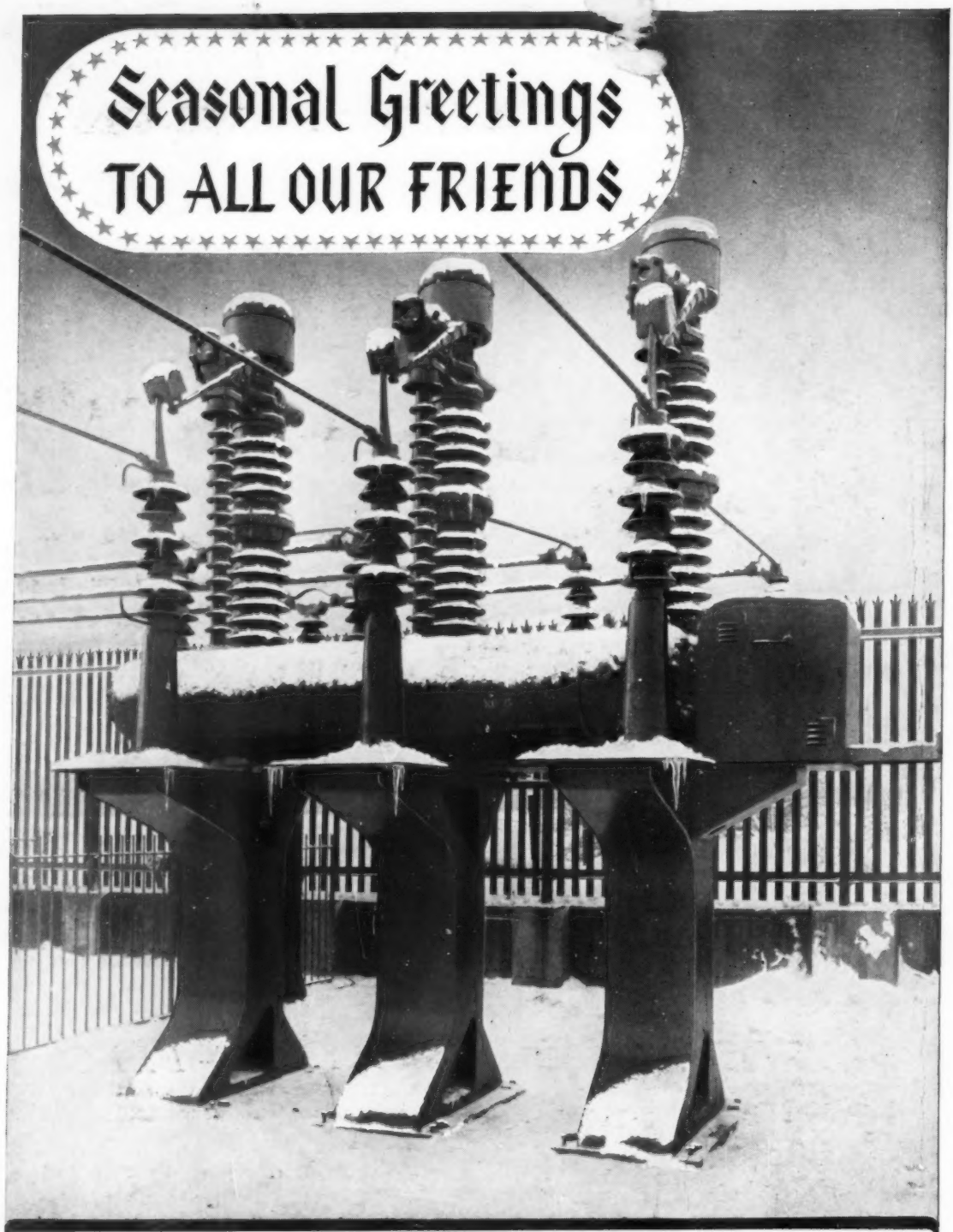


THE JOHN CRERAR LIBRARY
APR 19 1951

HYDRO-ELECTRIC
POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
Member of the A.E.I. group of companies



A. REYROLLE & COMPANY LTD
HEBBURN ★ Co. DURHAM ★ ENGLAND

GLENFIELD
CONTROL VALVES

for Hydro-electric
Power Plants

The Anti-vacuum Valve

LOCATED at changes of gradient or immediately downstream of automatic self-closing valves in LARGE STEEL PIPELINES, TO OPEN AUTOMATICALLY on the formation of vacuum which may occur at change of load, when the pipeline is being drained, or in event of a burst, and thus by permitting the free inflow of air TO SAFEGUARD THE PIPELINE AGAINST COLLAPSE.

Glenfield
GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office and Works:
KILMARNOCK, SCOTLAND
BOMBAY OFFICE:
9, WALLACE STREET. P.O. BOX 443
CALCUTTA OFFICE:
FAIRLIE HOUSE, FAIRLIE PLACE
P.O. BOX 2115
Representatives in most countries

L627.052
W31

RAPIER

Water Control Gates

SUKKUR BARRAGE · RIVER INDUS

The Sukkur Barrage on the River Indus, Pakistan, is nearly a mile long and includes 66 RapieR Barrage Gates, each 60 feet span for flood control.

Each of the seven main Canal Head Regulators consists of a series of 3-tier Gates provided with Electric Operating Gates.

Altogether nearly 600 RapieR Gates are employed in this vast project controlling a 5,000 mile canal system providing irrigation for 80,000 square miles.

We are now building gates for the new Kotri Barrage 200 miles farther down-stream—a repeat order after 20 years' experience of the Sukkur installation.

ONE OF THE SEVEN MAIN CANAL HEAD REGULATORS

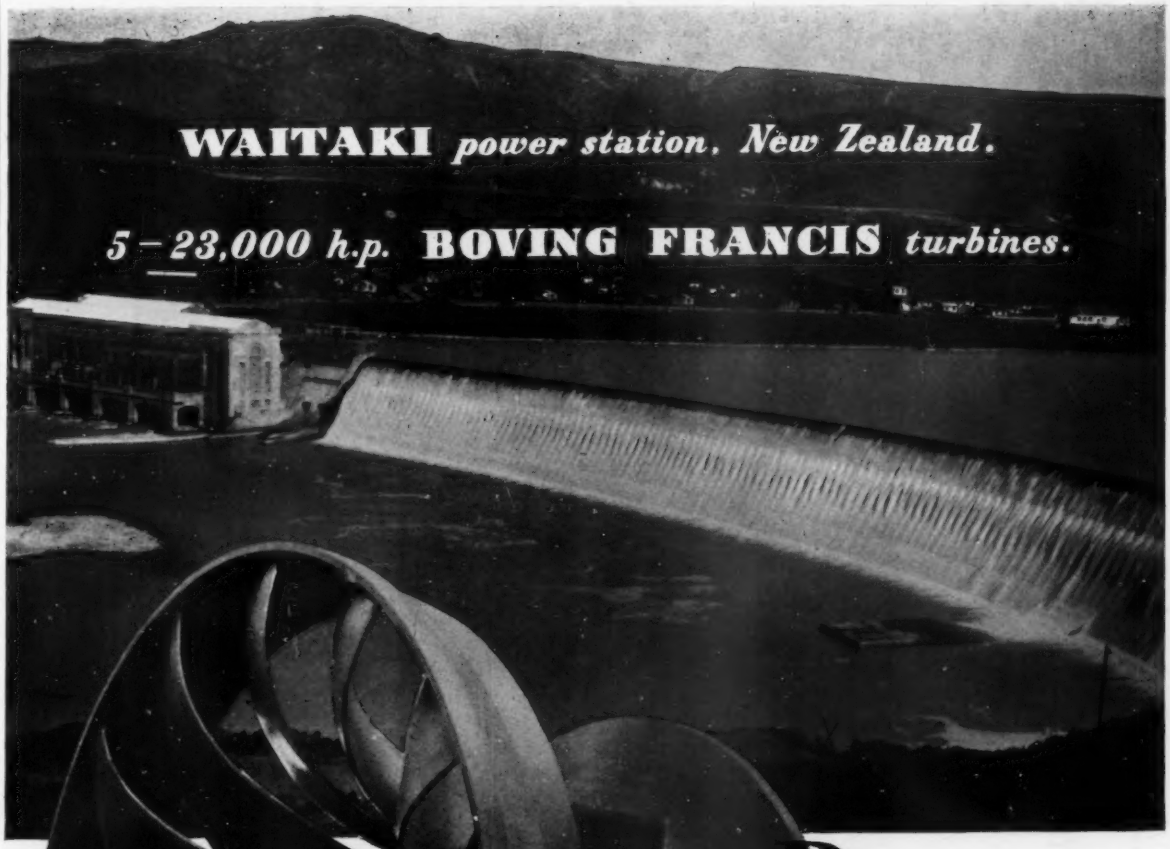
- *RIVER CONTROL*
- *IRRIGATION*
- *POWER PLANTS*
- *WATER SUPPLY*
- *LOCKS & DOCKS*

MOBILE CRANES · EXCAVATORS
WATER CONTROL
RAPIER
RAILWAY PLANT
CONTRACTORS PLANT

RANSOMES & RAPIER LTD. ENGLAND

IPSWICH—Waterside Works

32 Victoria Street—**LONDON**



Boving

The Waitaki power station is at present being extended with two BOVING-FRANCIS turbines. The station will then contain seven main turbines, all but the third and fourth being supplied by BOVING. The fabricated runner for one of these turbines is illustrated.

RATING	
Nett head	70 ft.
Output	23,000 b.h.p.
Speed	125 r.p.m.
Type	Vertical BOVING-FRANCIS
Diameter of runner	12.3 ft.

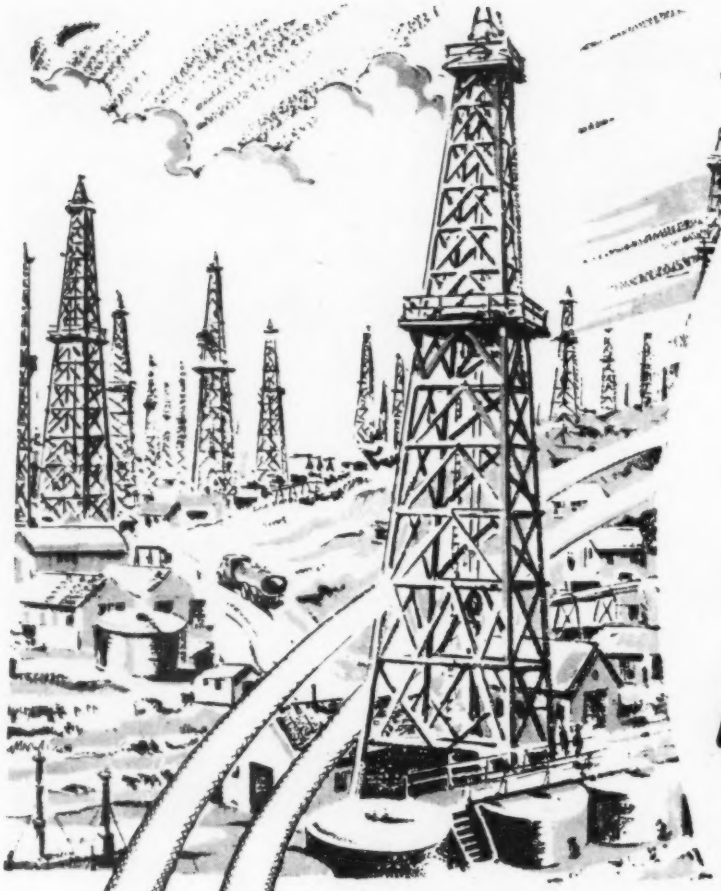
Boving
E. COMPANY LIMITED

WATER POWER ENGINEERS

Head Office:
56, KINGSWAY, LONDON, W.C.2, ENGLAND

Branch Offices: Wellington: Druids Chambers, Woodward Street.
Melbourne: 99 Queen Street.
Calcutta: c/o Messrs. Macneill & Barry Ltd., 2 Fairlie Place.
Chittagong: (Pakistan.) c/o Messrs. Macneill & Barry Ltd., Strand Road.

B.C.11



we don't produce the oil but

—in the production of Oil-Filled Cable—as indeed of all types of cable—the Pirelli-General Cable Works is a *complete* manufacturing unit. As with other raw material used, so with Oil. On delivery it passes immediately into the control of men w' ose job it is to condition it for one highly specialised purpose—that of cable manufacture. P-G chemists and technicians test the Oil for dielectric strength, power factor and electrical stability. They clarify and degasify it until as processed oil it is again tested before being pumped into pressurized reservoirs for ultimate use in oil-filled cables, joints and accessories—all top-grade products worthy of the name PIRELLI-GENERAL.

P G

33 kV to 330 kV

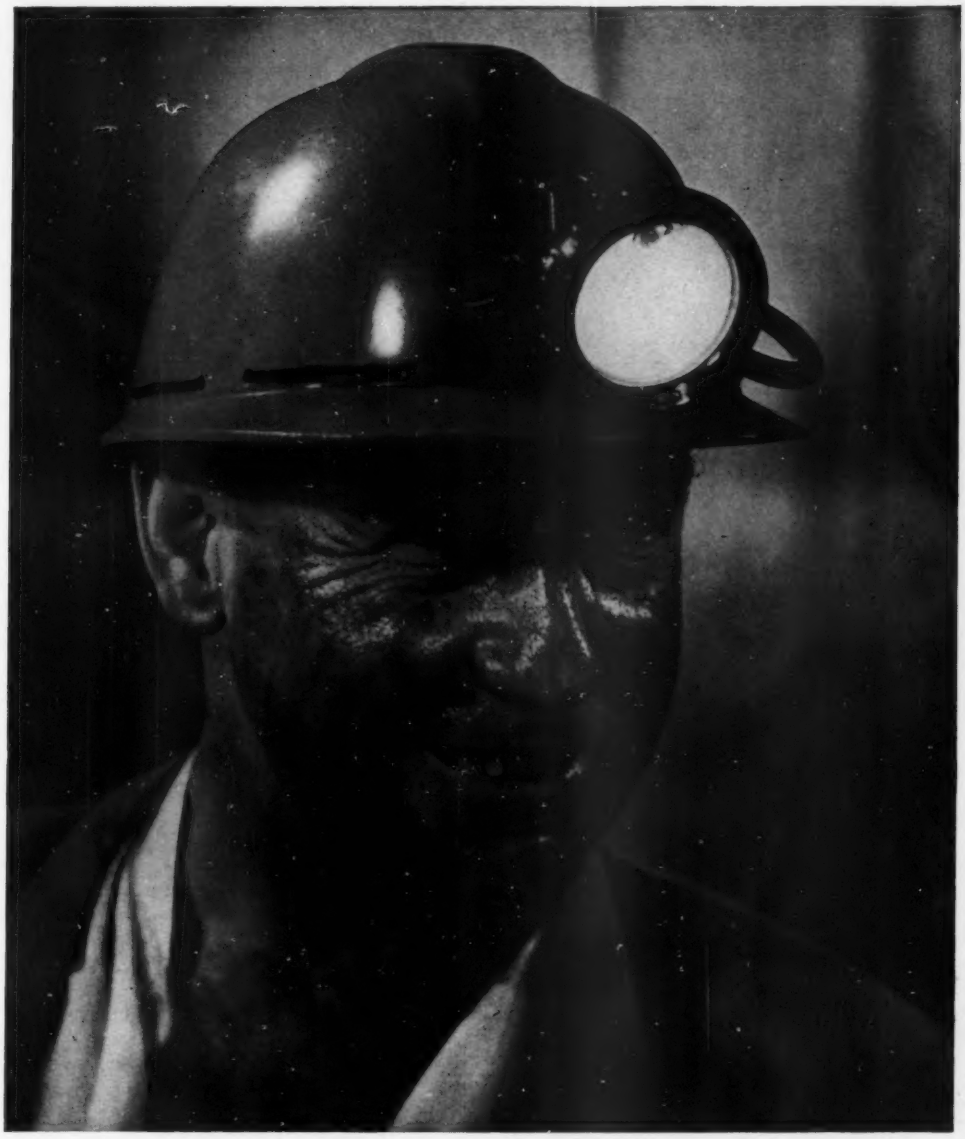
OIL-FILLED SUPER TENSION CABLE

PIRELLI-GENERAL

MANUFACTURERS OF EVERY KIND OF ELECTRIC CABLE

PIRELLI-GENERAL CABLE WORKS LTD., SOUTHAMPTON. *(An Associate of The General Electric Co., Ltd.)*

1951
INTRODUCES
THE MODERN "PANORAMA" PLASTIC SAFETY HELMET



FEATURES:

1. To British Standard Specification (Revised)
2. Light Weight
3. High degree of chemical resistance
4. Complete resistance to moisture
5. Permanently fast colours
6. Long life
7. Competitive colours

Available with or without lamp brackets

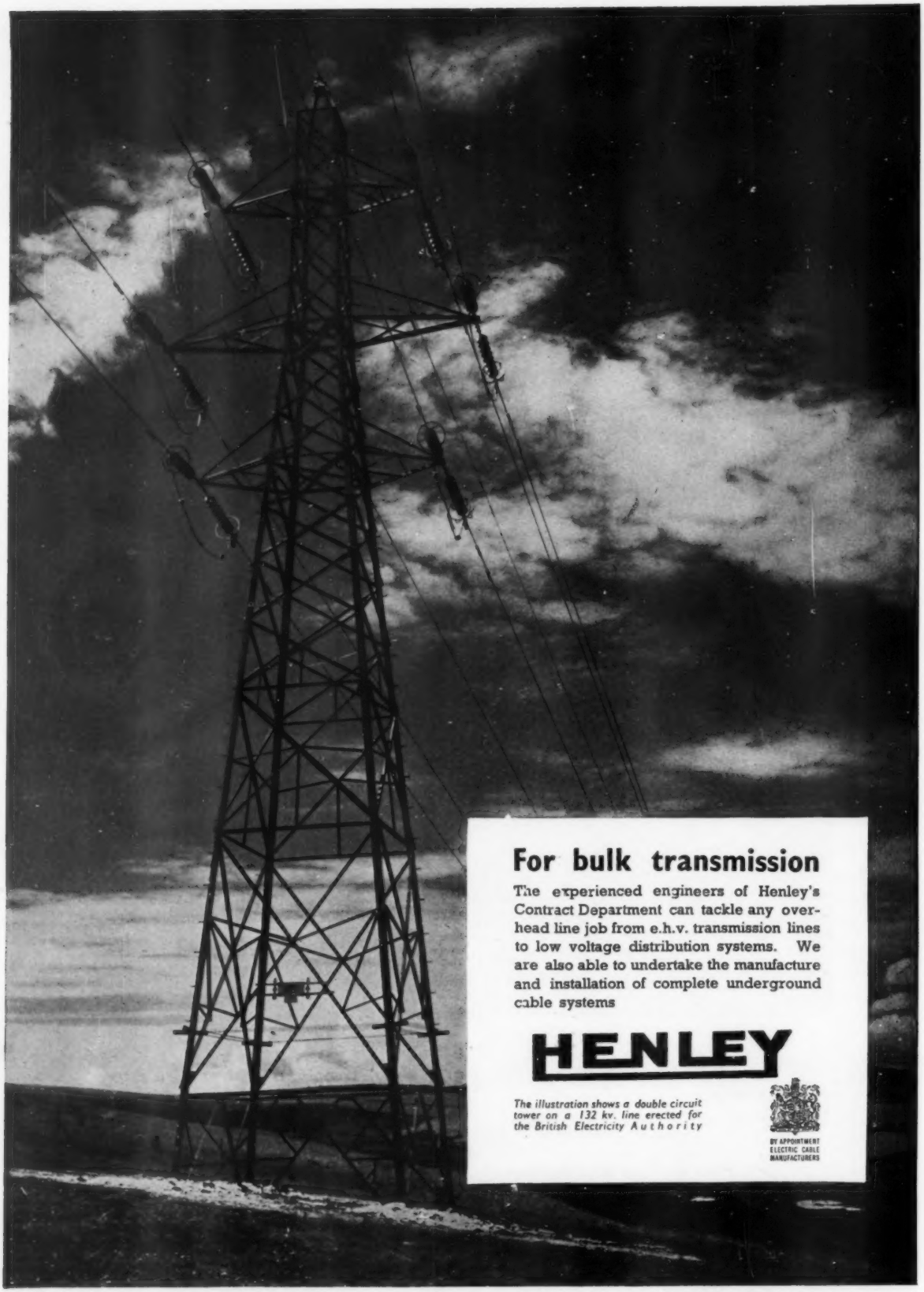
In all sizes. Colours: Black, White, Brown, Red. In cartons of six.

Full details from sole manufacturers:

STRATFORD PRODUCTS SAFETY SERVICE CO. LTD.

98 TOWER BRIDGE ROAD, LONDON, S.E.1

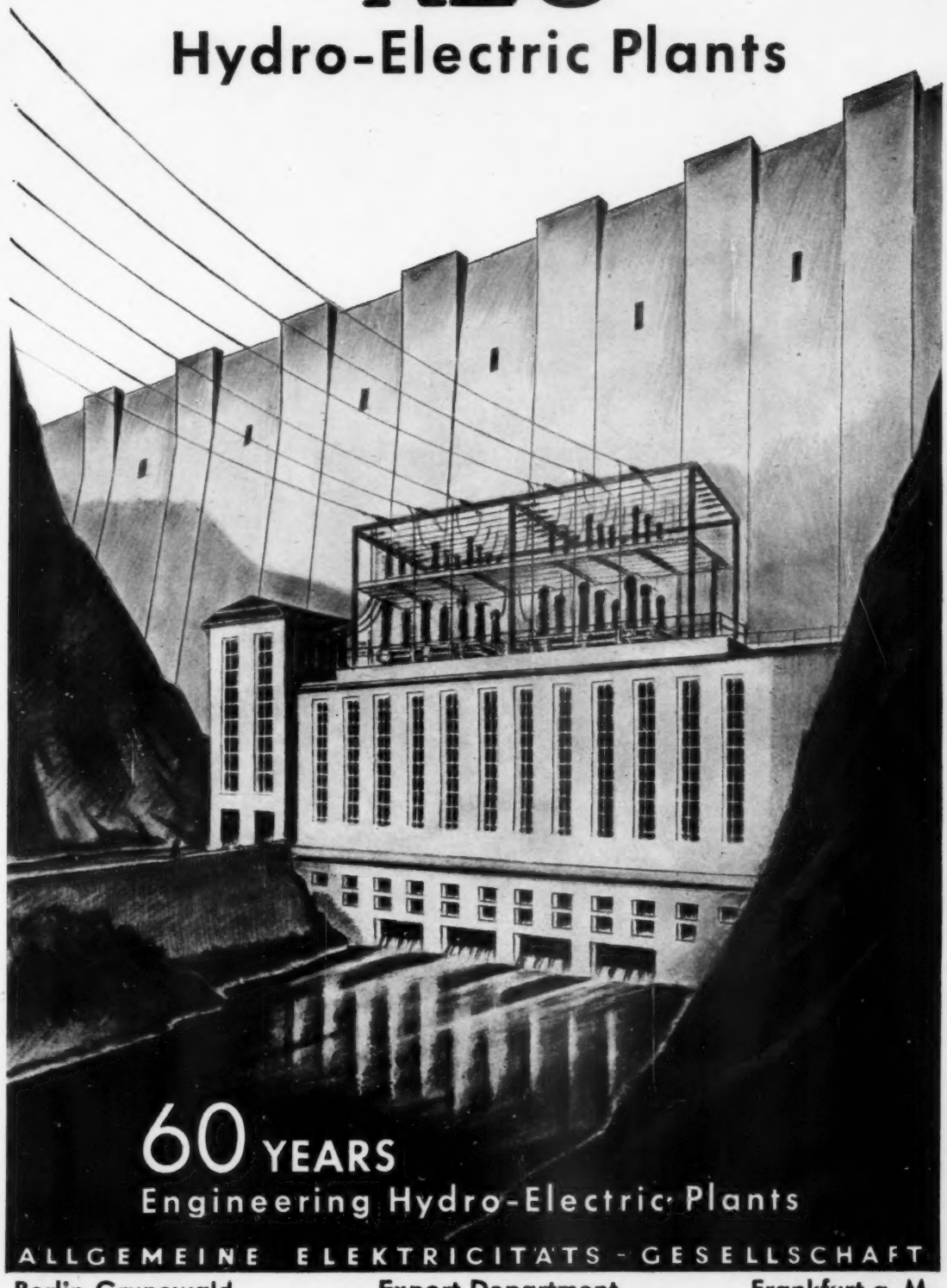
And at PARIS, BRUSSELS, JOHANNESBURG, TORONTO, WELLINGTON, RIO DE JANEIRO


For bulk transmission
The experienced engineers of Henley's Contract Department can tackle any overhead line job from e.h.v. transmission lines to low voltage distribution systems. We are also able to undertake the manufacture and installation of complete underground cable systems
HENLEY
The illustration shows a double circuit tower on a 132 kv. line erected for the British Electricity Authority
BY APPOINTMENT ELECTRIC CABLE MANUFACTURERS

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD. · 51-53 HATTON GARDEN, LONDON, E.C.1

AEG

Hydro-Electric Plants



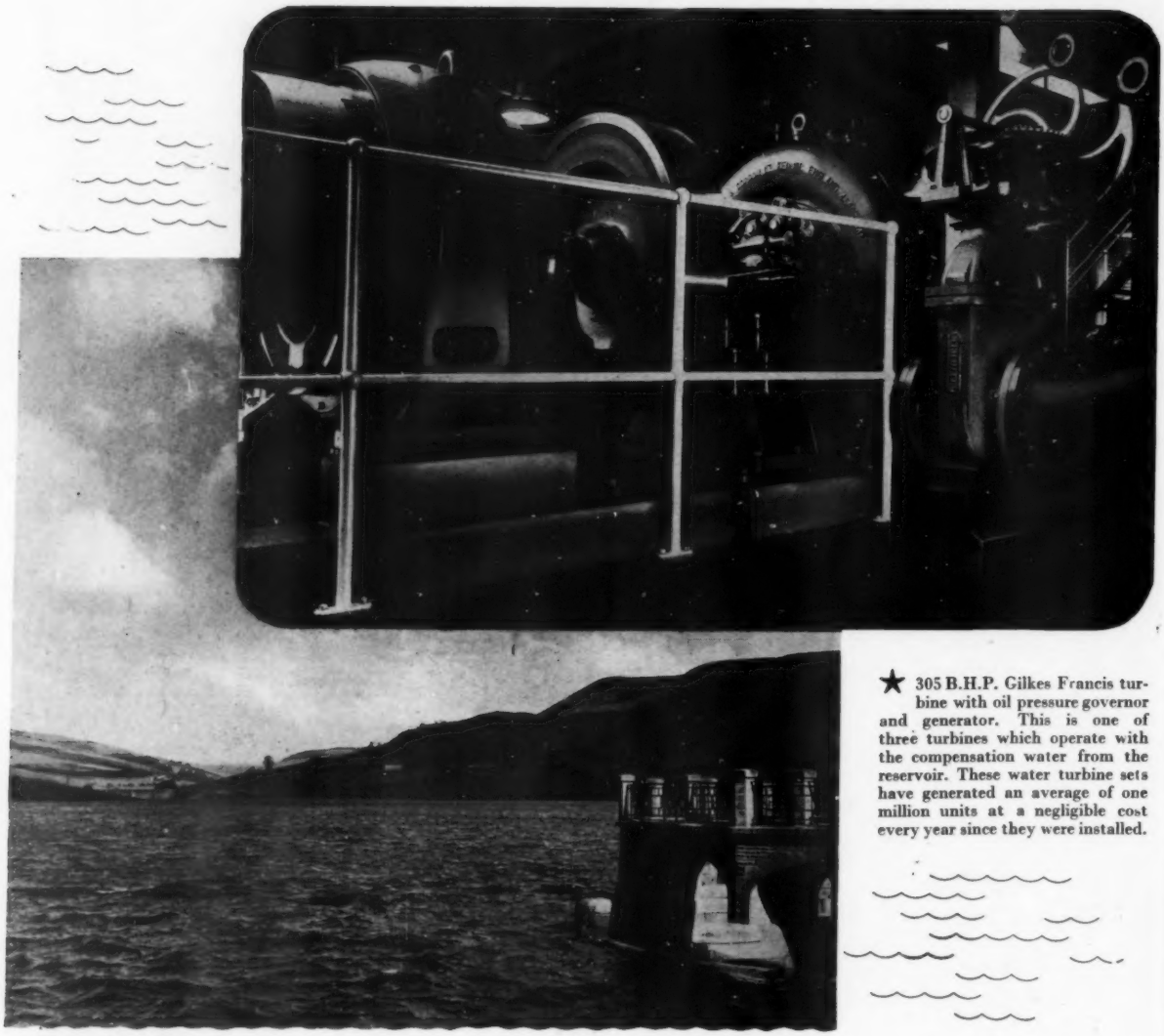
ALLGEMEINE ELEKTRICITÄTS - GESELLSCHAFT

Berlin-Grunewald Export Department Frankfurt a. M.

5196

GILKES WATER TURBINES

at the Ladybower Reservoir, Ashopton, Derbyshire



★ 305 B.H.P. Gilkes Francis turbine with oil pressure governor and generator. This is one of three turbines which operate with the compensation water from the reservoir. These water turbine sets have generated an average of one million units at a negligible cost every year since they were installed.

At the Ladybower Reservoir, one of the largest stretches of artificial water, the Derwent Valley Water Board has installed three Gilkes Water Turbines totalling 660 B.H.P.

GILBERT GILKES & GORDON LTD

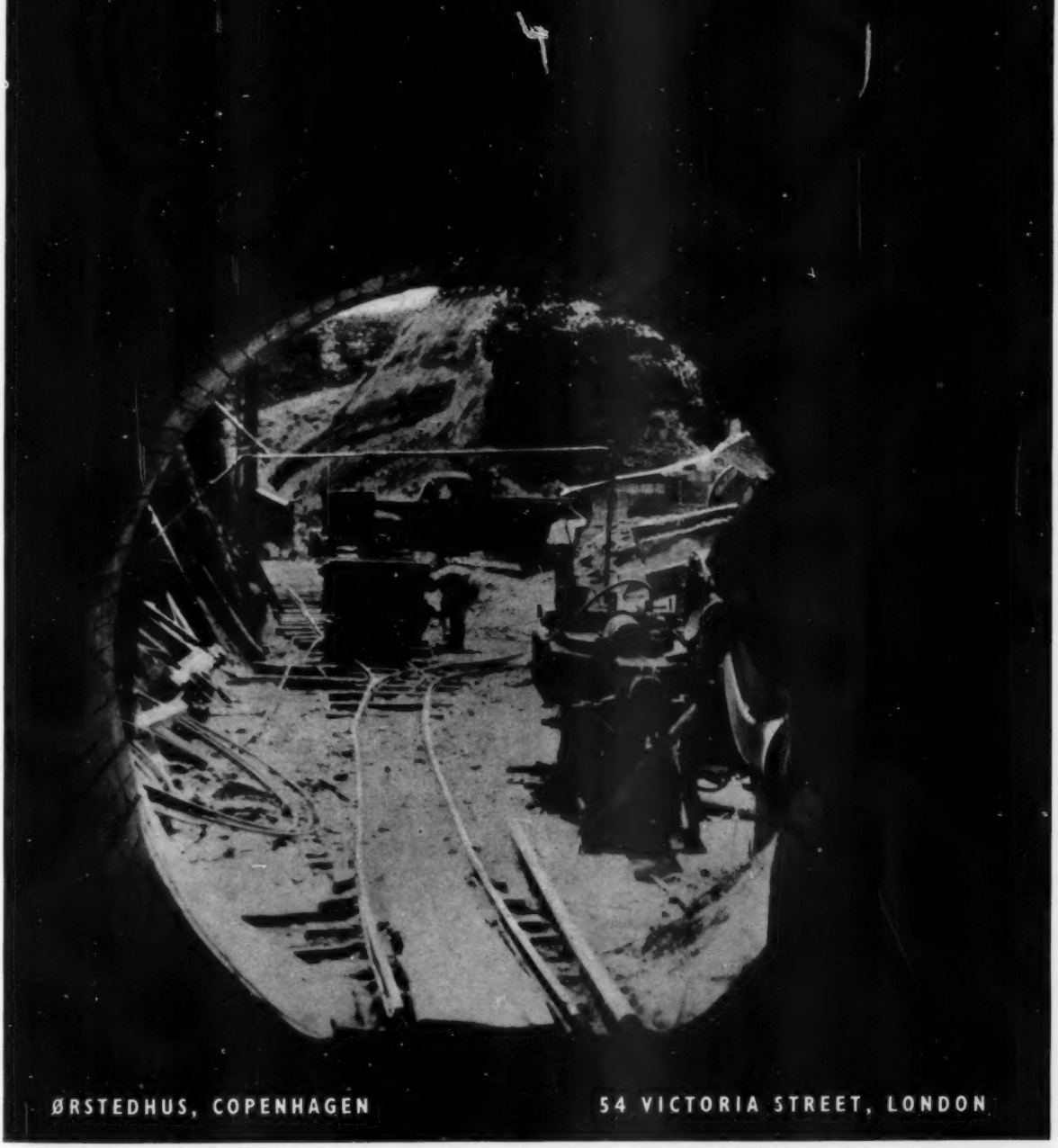
KENDAL 'Phone: Kendal 28 ENGLAND

WATER TURBINE AND PUMP MANUFACTURERS

London Office: CRAVEN HOUSE, KINGSWAY, LONDON W.C.2 'Phone: Holborn 3232

G. 29

CHRISTIANI & NIELSEN



ØRSTEDHUS, COPENHAGEN

54 VICTORIA STREET, LONDON

The safe link

We specialise in manufacturing Power Transformers for Generation. Transmission and Distribution. All YORKSHIRE Transformers are designed, constructed and tested to the corresponding British Standard Specification.

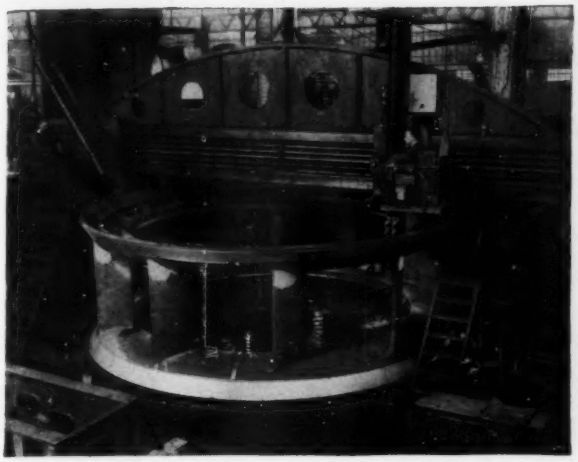
We make Transformers to suit all requirements up to 45,000 k.V.A. - 132,000 volts.

YORKSHIRE TRANSFORMER

YET

Phone. DEWSBURY 1691/2

YORKSHIRE ELECTRIC TRANSFORMER Co LTD DEWSBURY · ENGLAND



FOUNDRIES • PLATE FABRICATING • MACHINING • ASSEMBLY

Complete Facilities for the Production of

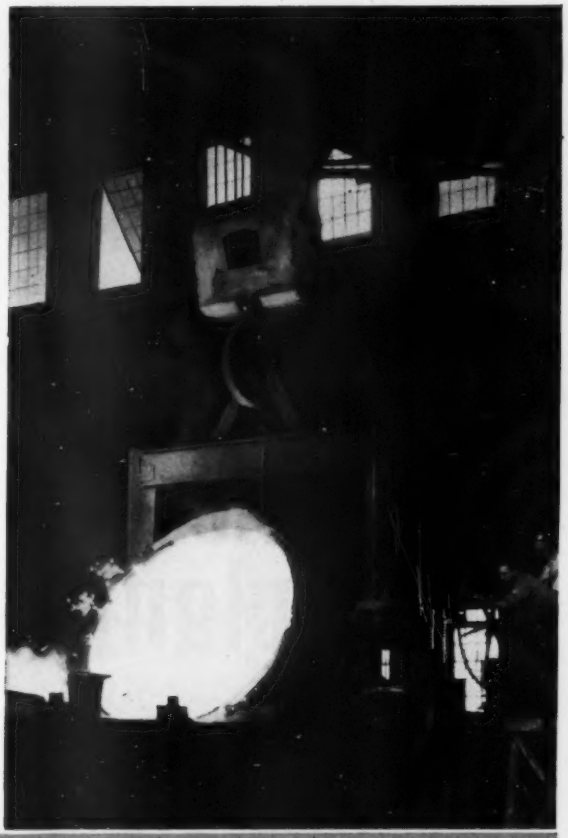
HYDRAULIC TURBINES

Francis, Propeller or Impulse—small, medium or large—at Dominion Engineering are the complete facilities and the long, specialized experience to produce them.

Here, for example, are foundries which produce iron, steel and bronze castings. Here, too, are plate steel and machine shops equipped with a complete variety of tools to fabricate any size or type of turbine.

The extent of such facilities is your assurance of quality production and good deliveries to any part of the world. Dominion Engineering is at your service whenever you are considering new water power developments.

Write to P.O. Box 220, Montreal, for Hydraulic Turbines Bulletin No. 201.



DOMINION ENGINEERING
COMPANY LIMITED

MONTREAL, CANADA **D** CABLE: DOMWORKS

The harnessing of Loch Fannich...

The Loch Fannich project in Ross-shire, Scotland, is part of the North of Scotland Hydro-electric Board's plan to provide hydro-electric power to feed a 132,000 volt grid serving Northern Scotland.

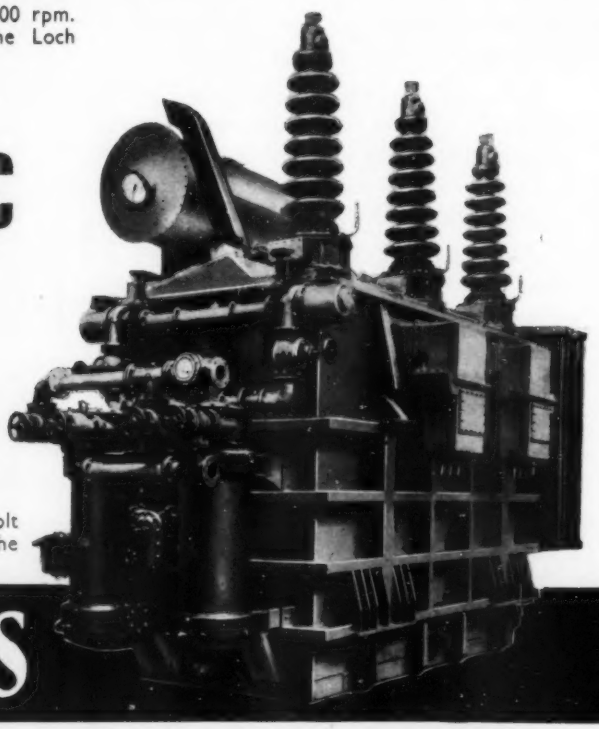
The power station at Grudie Bridge will house two 13,333 kVA Francis turbo-generators directly connected to two 20,000 kVA transformers.

13,333 kVA. 11,000 volt, 500 rpm. vertical generator for the Loch Fannich scheme.

PEEBLES

hydro-electric plant

Bruce Peebles build large and small generators for all types of water turbines, and transformers up to the largest sizes for hydro-electric power distribution.



20,000 kVA. 132,000/11,000 volt water-cooled transformer for the Loch Fannich scheme.

BRUCE PEEBLES

Advertisement of BRUCE PEEBLES & CO. LTD. · ENGINEERS · EDINBURGH · SCOTLAND

THE CLAERWEN DAM

for the

BIRMINGHAM CORPORATION
WATER DEPARTMENT

*

A. E. Fordham, A.I.M.T.A., P.A.I.W.E., General Manager and Secretary

C. A. Risbridger, B.Sc., M.I.C.E., M.I.W.E., Chief Engineer.

Consulting Engineers: Sir William Halcrow & Partners, M.M.I.C.E.

*

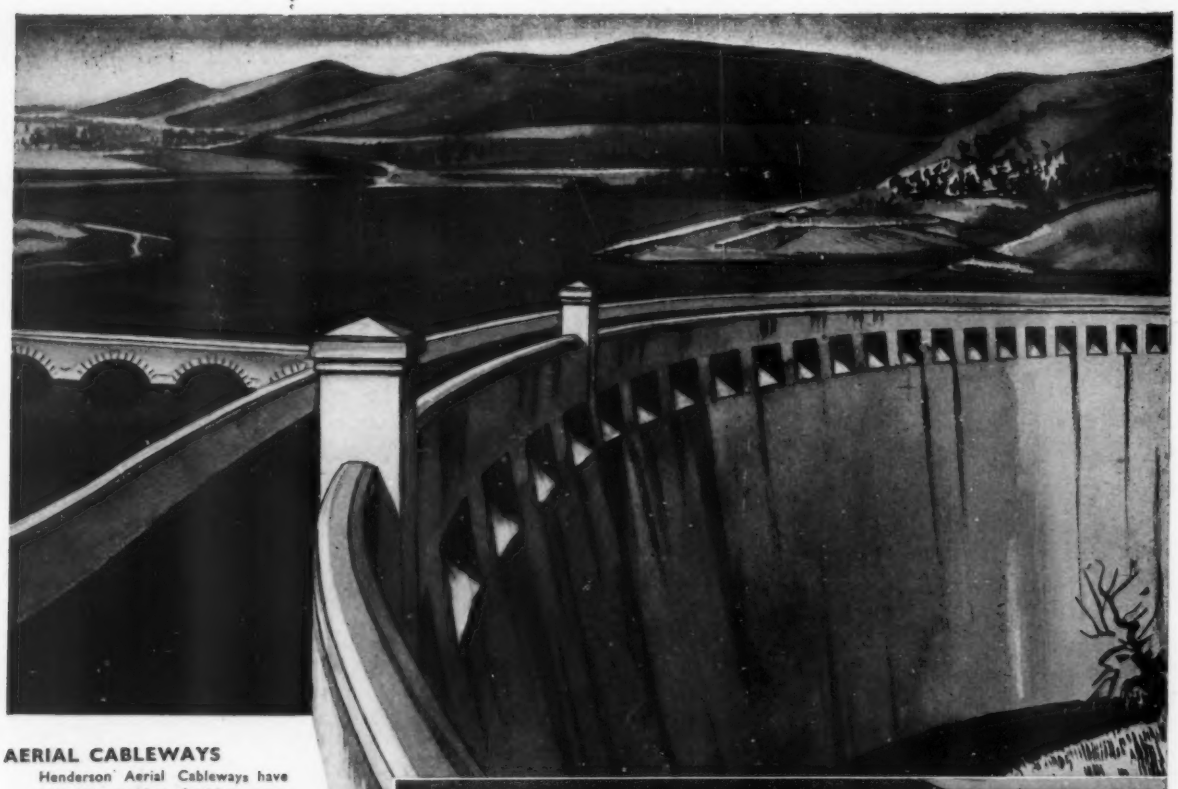
EDMUND NUTTALL

SONS & COMPANY (LONDON) LTD

CIVIL ENGINEERING CONTRACTORS

22, GROSVENOR GARDENS, LONDON, S.W.1.

E.N. 19



AERIAL CABLEWAYS

Henderson Aerial Cableways have solved the problem of raising, transporting and depositing concrete, shuttering and other materials for the construction of large Dams and Barrages.

Henderson Cableways are being used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

DERRICK CRANES

Henderson Cranes are chosen so often because of their speed and versatility in lifting materials. Their safety and economy in operation are also assured. Supplied to many leading contractors Henderson Derrick Cranes of all types and capacities can be manufactured for steam, electric, petrol or diesel drive. Cranes can also be fixed or travelling types. Normal sizes are from 10 cwt. to 60 tons Load capacity. With jibs up to 120 feet.

View of Henderson Cableways during the construction of the Cloerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd.

Henderson

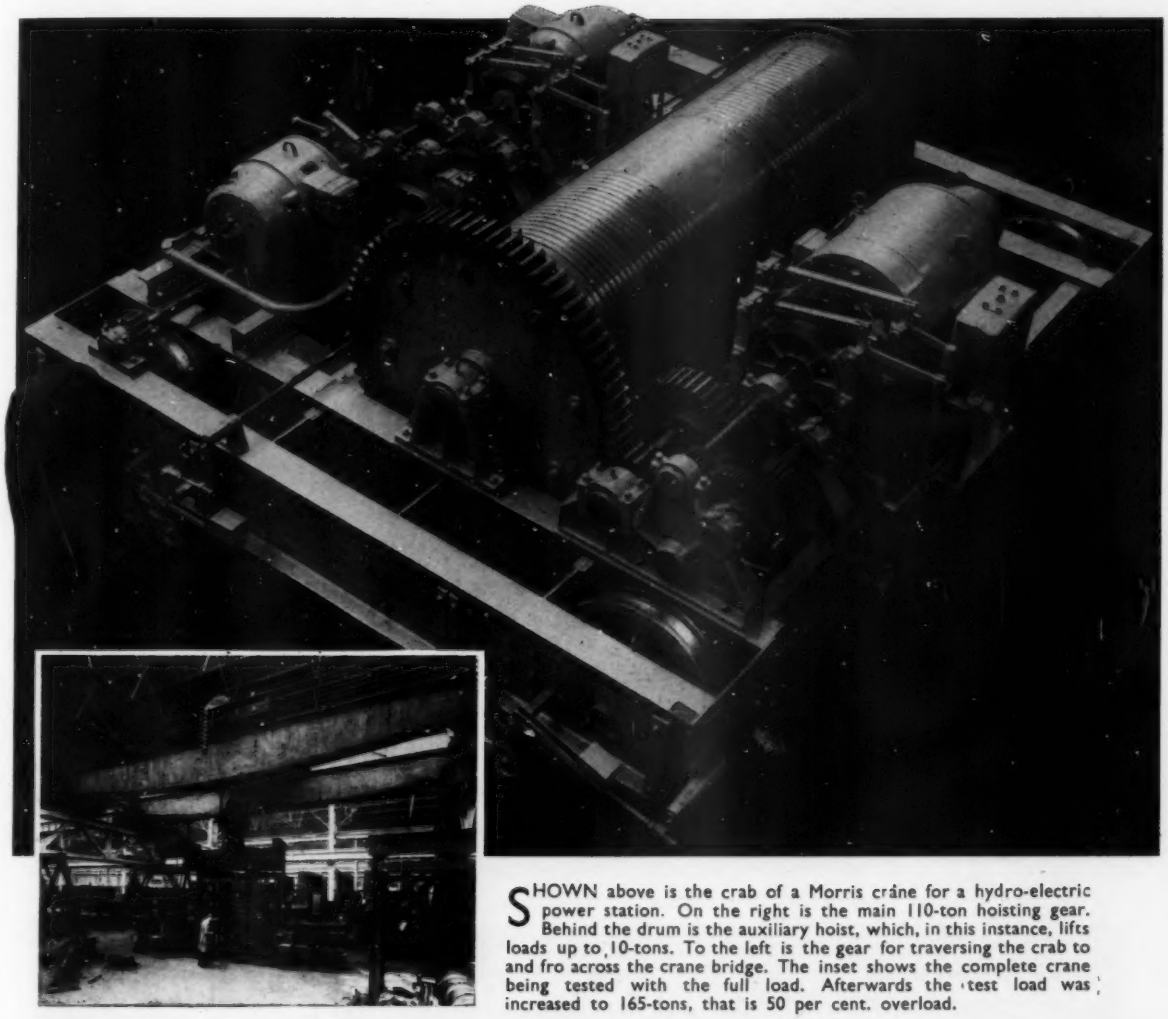
Aerial Cableways

AND DERRICK CRANES

FOR HYDRO ELECTRIC SCHEMES

JOHN M. HENDERSON AND COMPANY LIMITED KING'S WORKS ABERDEEN

Cranes for the power station



SHOWN above is the crab of a Morris crane for a hydro-electric power station. On the right is the main 110-ton hoisting gear. Behind the drum is the auxiliary hoist, which, in this instance, lifts loads up to 10-tons. To the left is the gear for traversing the crab to and fro across the crane bridge. The inset shows the complete crane being tested with the full load. Afterwards the test load was increased to 165-tons, that is 50 per cent. overload.

MORRIS

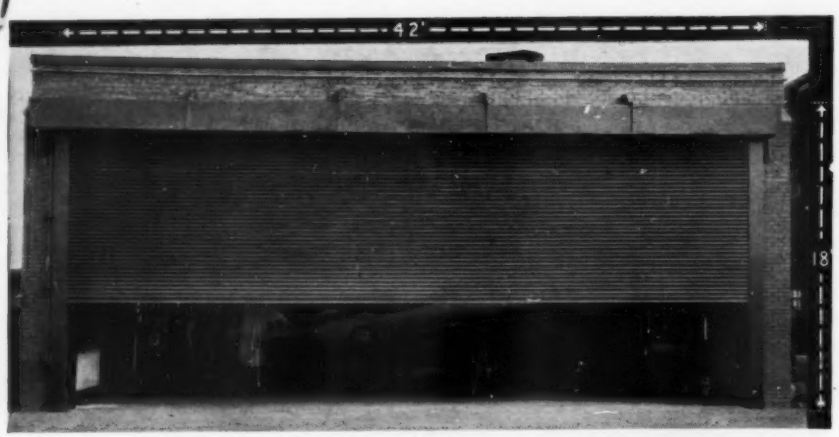
HERBERT MORRIS LTD., LOUGHBOROUGH, ENGLAND

Like Britain

CANADA CHOOSES BRADY

Land of unusual attainments, Canada also has unusual requirements, but when the Canadian Car & Foundry Company of Montreal wanted a giant 'rolling door' far beyond the usual specification, it was not beyond Brady. Ordered on January 28th, 1949, it was despatched on July 12th, 1949, and in operation on August 5th, 1949; proof that the Brady organisation can tackle out-of-the-ordinary rolling shutter problems as efficiently as the standard installations which have won 'Brady Roller Shutters' an international grading.

This Brady project, 42' × 18' is an object of interest in Montreal, commercial capital of the Dominion, headquarters of the C.P.R., where it is one of the largest 'rolling doors' ever planned and created.



G. BRADY & CO. LTD · ANCOATS · MANCHESTER 4 · Phone: COLlyhurst 2797/8

LONDON: New Islington Works, Park Royal, N.W.10 — BIRMINGHAM: Rectory Park Road, Sheldon 26

CANADA: c/o DAVID C. ORROCK & CO. 1405 Bishop Street, MONTREAL 25.

Manufacturers of Brady Hand and Power Operated Lifts

Stowe & Bowden

GREATEST FOOTAGE—LEAST FATIGUE

The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

CLIMAX

CLIMAX ROCK DRILL & ENGINEERING WORKS LTD.

4, Broad Street Place, London, E.C.2. Works: Carn Brea, Cornwall.

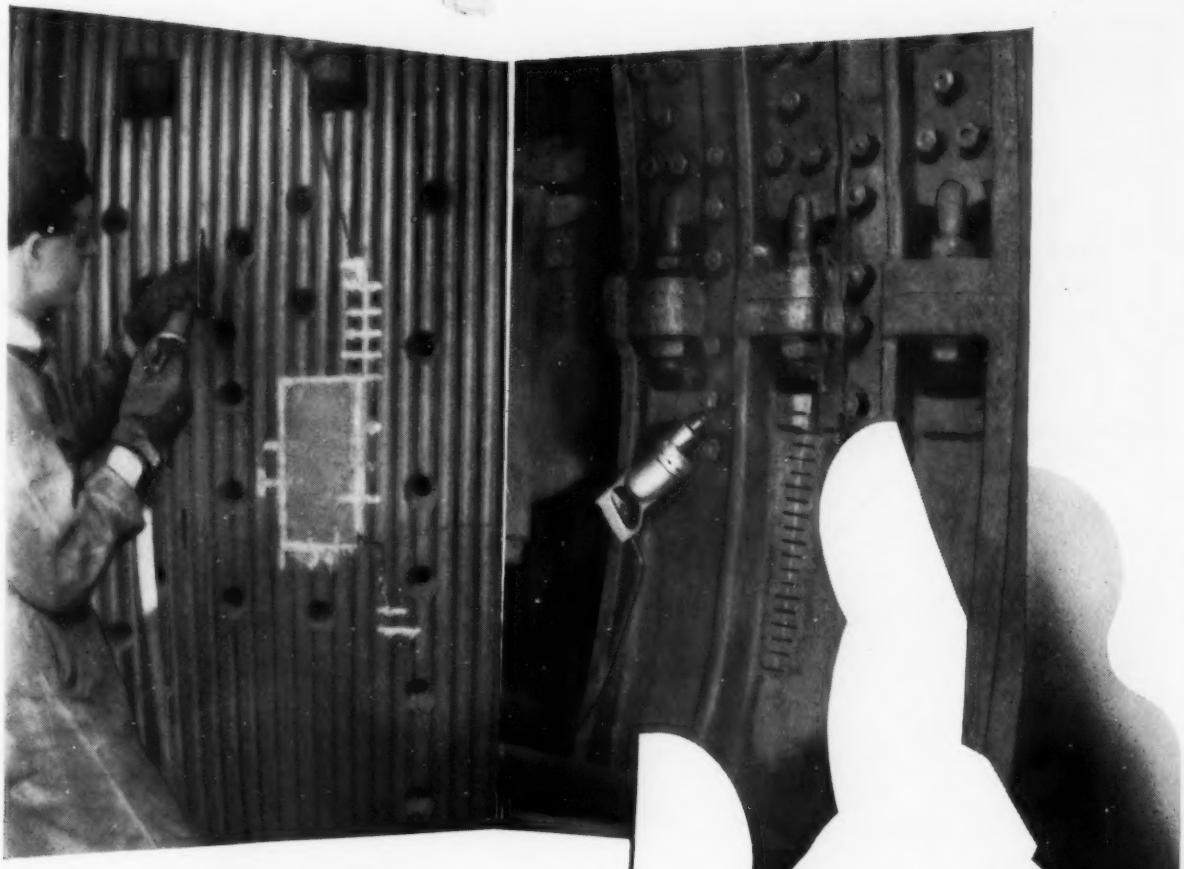
TAS/CX 480

Richard
COSTAIN
Limited

Building and Civil Engineering Contractors
FOR THE FESTIVAL OF BRITAIN 1951 EXHIBITION;
AND FOR THE
L.C.C. SOUTH BANK RECONSTRUCTION SCHEME,
COMPLETED THREE MONTHS AHEAD OF SCHEDULE

HEAD OFFICE: DOLPHIN SQUARE, LONDON, S.W.1

BRANCHES
TURKEY · MIDDLE EAST · RHODESIA · UGANDA · NIGERIA



COLD REPAIRS *without dismantling.*

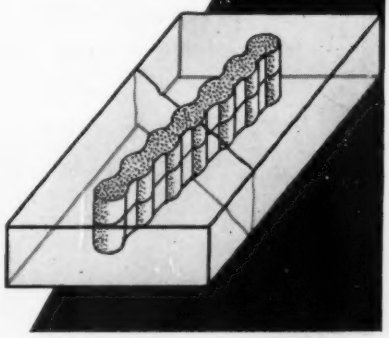
• ○ •

Two 25 ft. diameter Winding Drums repaired by " METALOCK " operators flown from England to Robinson Deep Gold Mine, Johannesburg, South Africa. A total of 67 ft. of fracture existed in these two Drums and they were kept in operation throughout the repair except for a shutdown period of one week on one Drum and four days on the other.

Write for descriptive literature—

METALOCK

"METALOCK" is the Trade Mark of the METALOCK REPAIR SERVICE, Inc., Long Island City, New York, for the special alloy strips used in machinery repairs

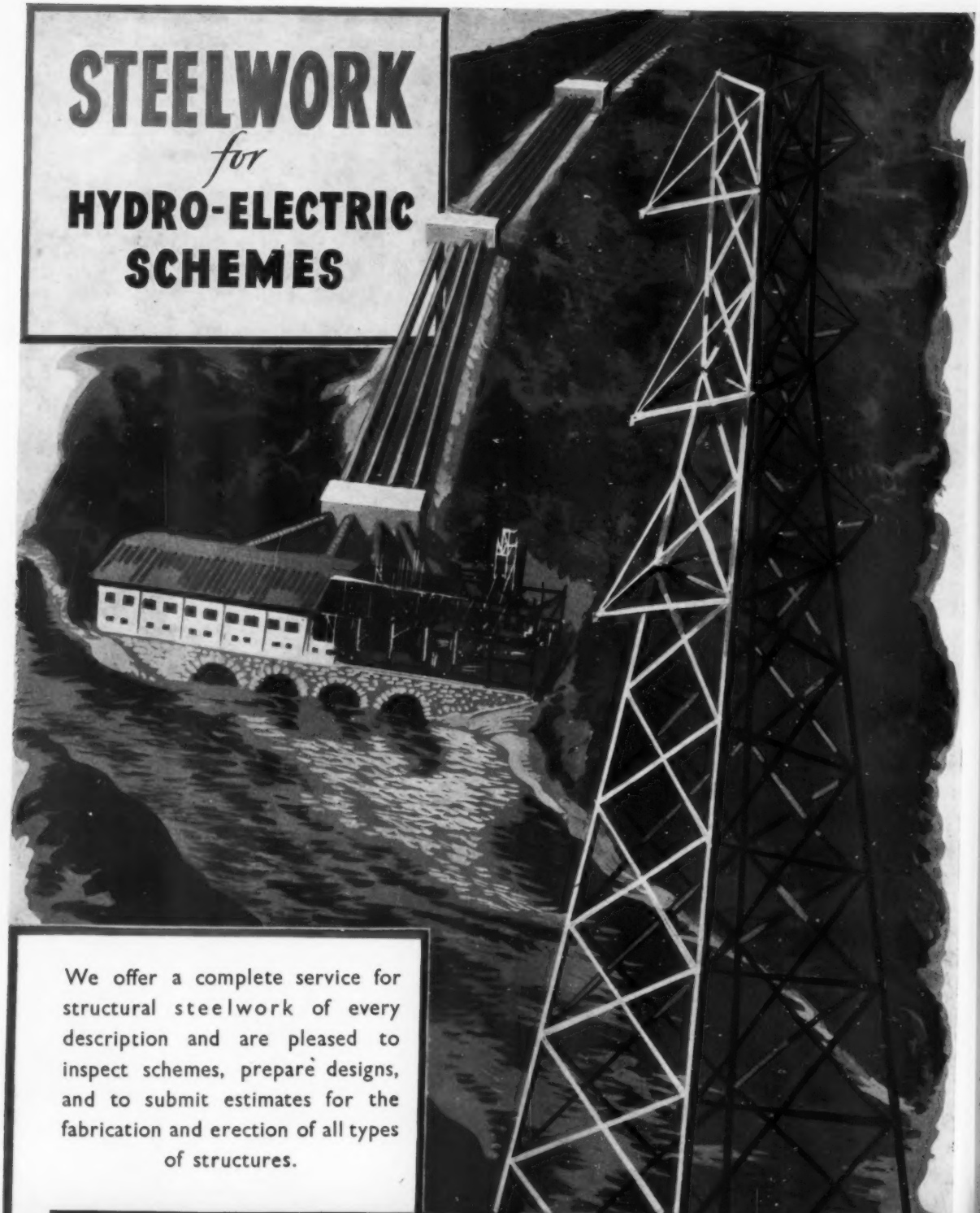


COLD REPAIR OF CASTINGS

METALOCK (Britain) LTD., Grand Buildings, Trafalgar Square, London, W.C.2

Telephone : Whitehall 4803 *Telegrams: Metlokcast, Rand, London*

STEELWORK
for
HYDRO-ELECTRIC SCHEMES

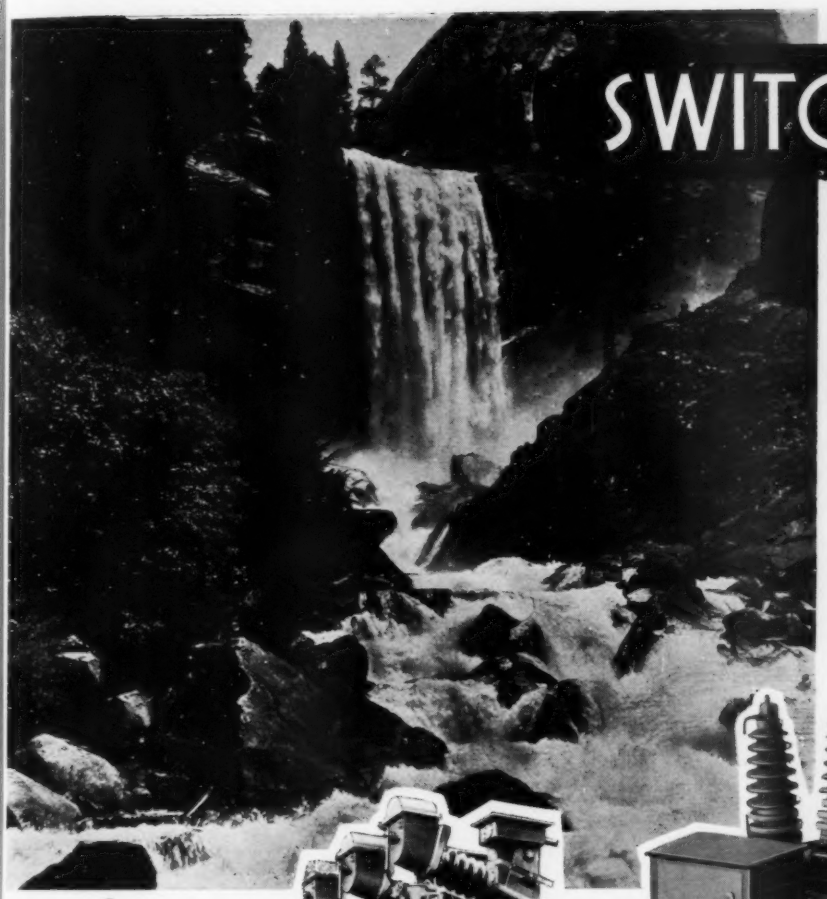


We offer a complete service for structural steelwork of every description and are pleased to inspect schemes, prepare designs, and to submit estimates for the fabrication and erection of all types of structures.

ROBINSON and KERSHAW LTD

TEMPLE STEELWORKS · GLOBE LANE · DUNKINFIELD · CHESHIRE

Telegrams: 'GRILLAGE' Ashton-under-Lyne

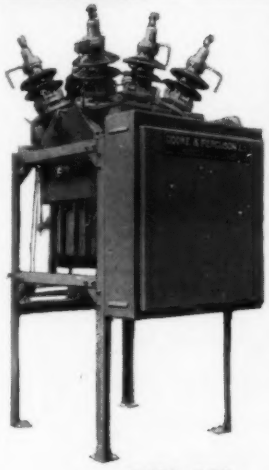


SWITCHGEAR

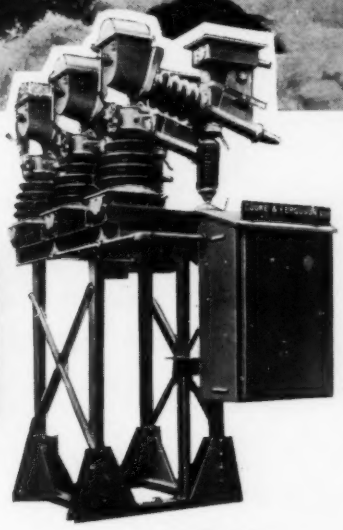
for

HYDRO ELECTRIC SCHEMES

Three examples from the C and F range of Outdoor Oil Circuit Breakers are illustrated below. The complete range extends from 2,000 volts to 138 kV for both indoor and outdoor service under the most arduous conditions.



TYPE OE5
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
1,500 M.V.A. 34.5 kV (A.S.A.)
1,000 M.V.A. 33kV (B.S.)

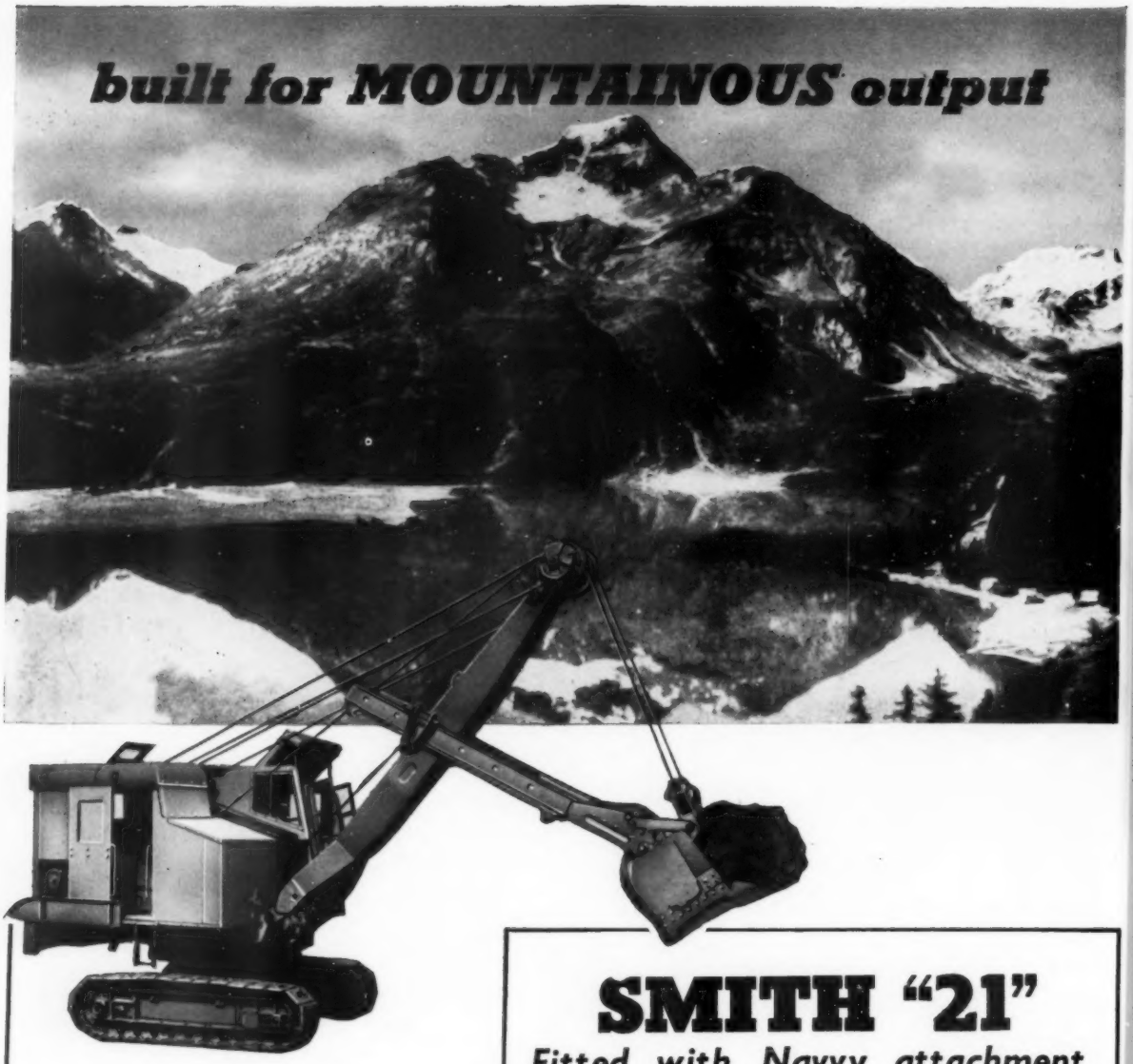


TYPE OE6
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
1,500 M.V.A. 46kV (A.S.A.)
1,500 M.V.A. 44kV (B.S.)

TYPE OF1
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
1,000 M.V.A. 69 kV (A.S.A.)
750 M.V.A. 66 kV (B.S.)

FULL PARTICULARS SENT ON APPLICATION

COOKE & FERGUSON Ltd.
Switchgear Specialists
VICTORIA STREET OPENSHAW MANCHESTER 11



SMITH "21"

Fitted with Navvy attachment

If the total output of a Smith 21 could be finally dumped in bulk, the effect would be—earth-shaking! The '21' is not only robustly constructed and amply powered but, being highly mobile and easily manoeuvred, may be put to almost any class of excavation. It is quickly convertible by means of the usual front-end attachments which include dragshovel, dragline, skimmer and crane.

Standard bucket capacity: ¾ cubic yard.

SMITH cranes and excavators

THOMAS SMITH & SONS (RODLEY) LTD CRANE & EXCAVATOR WORKS RODLEY LEEDS

Specialists in the design and manufacture of Cranes and Excavators

2196

TUNNEL AT BOWLAND FOR MANCHESTER CORPORATION WATERWORKS
Engineer and Manager—Alan Atkinson, Esq., M.Eng., M.I.C.E., M.Inst.W.E.

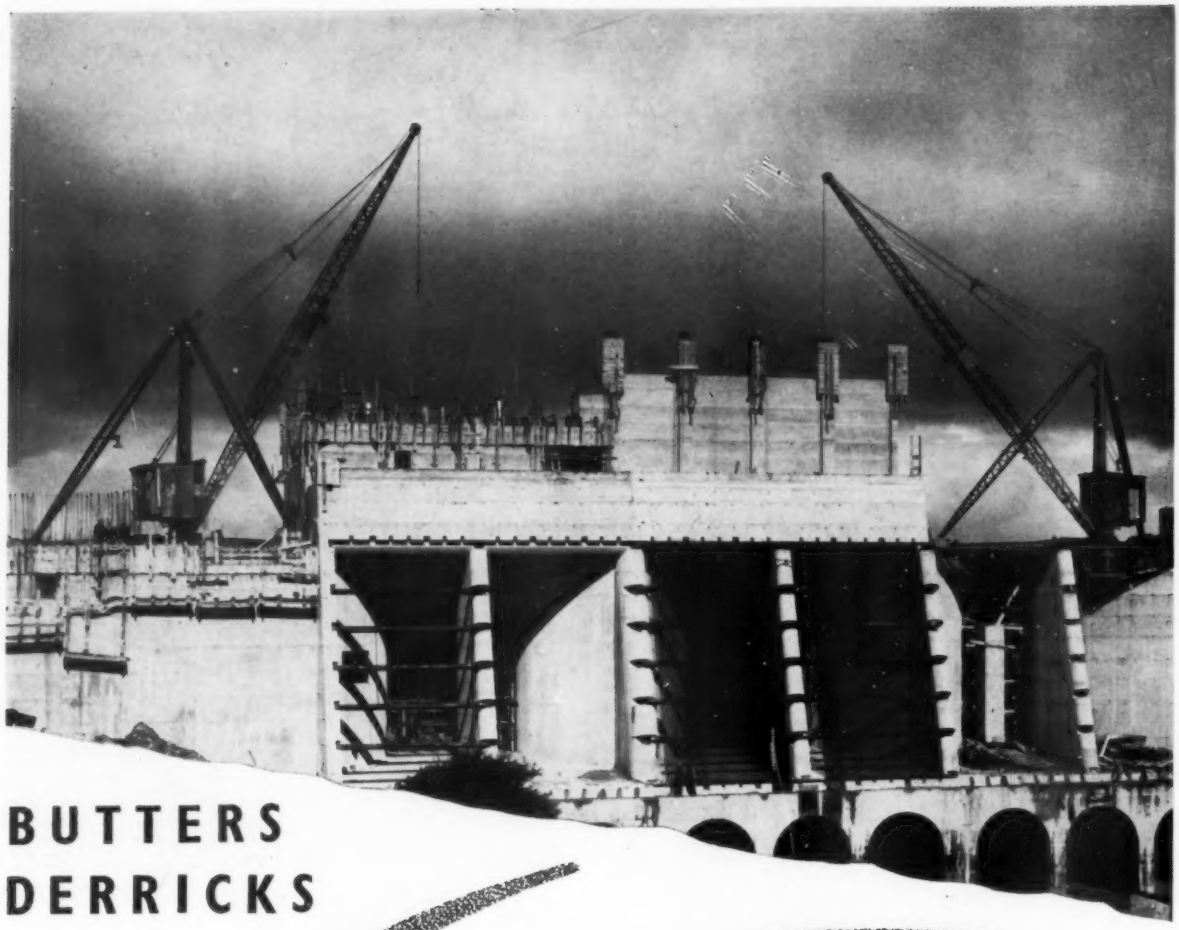
The
CEMENTATION
COMPANY LIMITED

This tunnel, ten miles long, forms the middle section of the aqueduct which when completed will bring water from Haweswater in the Lake District to Manchester. The conditions for tunnelling under the Bowland Hills are difficult, varying from soft mudstones to sandstones containing water at high pressure, such as in the heading shown above from which over two million gallons of water are being pumped each day. Despite these varying and difficult conditions, a progress of 236 feet has been obtained in one week in ground requiring continuous steel arch support right up to the face.

BENTLEY WORKS — DONCASTER

TELEPHONE: DONCASTER 54177-8-9

LONDON OFFICE 39 VICTORIA STREET, S.W.1 TELEPHONE: ABBEY 5726-7-8



BUTTERS DERRICKS

Another Successful Application

The Ballyshannon Hydro-Electric Scheme is nearing completion and this recent photograph shows two of several Butters Derricks which were in use throughout. The bridge on which they traverse the width of the dam is now masked by the masonry. These cranes are 5 tonners, electric, with 90 feet jibs.

THE MAIN CIVIL ENGINEERING CONTRACTORS ON THE BALLYSHANNON SCHEME ARE MESSRS. CEMENTATION CO. LTD., DONCASTER.

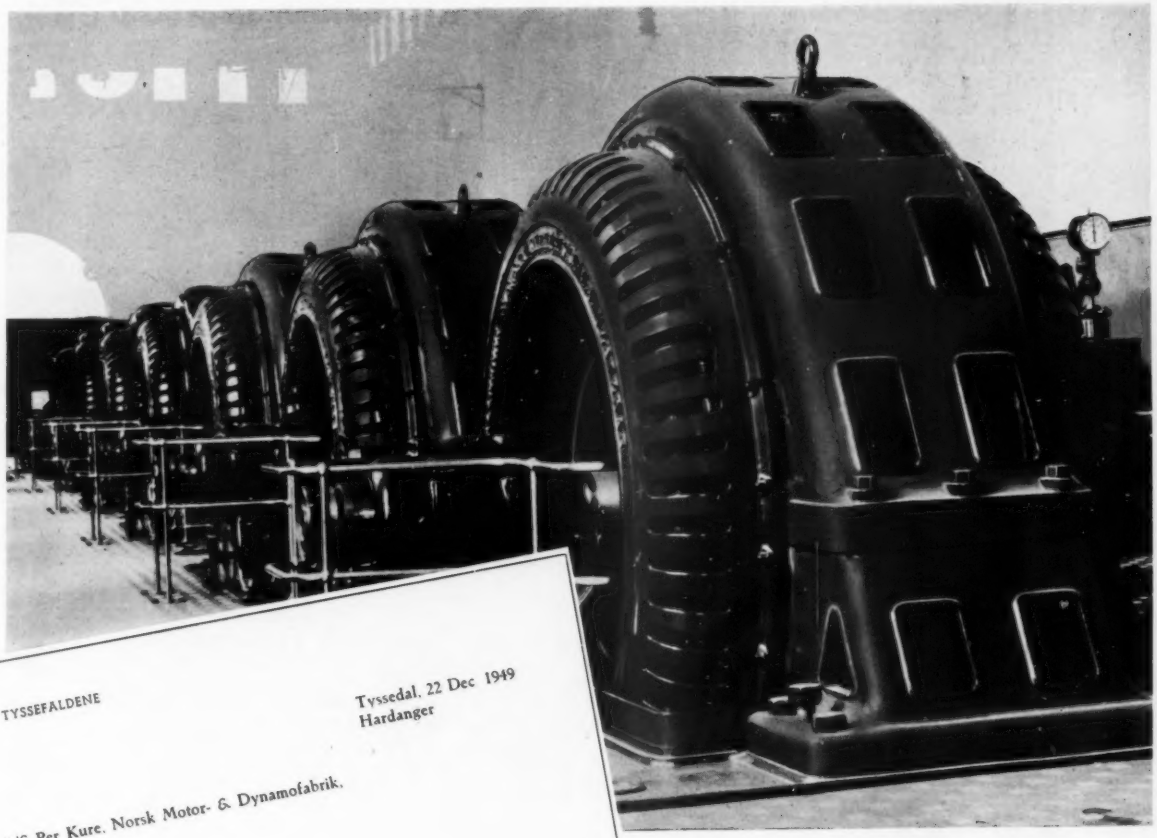
BUTTERS BROS. & CO. LTD.

MACLELLAN STREET, GLASGOW, S.1

Telephone: IBROX 1141 (6 lines) *Telegrams:* BUTTERS, GLASGOW

and at LONDON
BIRMINGHAM • NEWCASTLE

200,000
service hours
— corresponding to 24-28 years continuous service night and day — without interruption



Interior of Tysse power station, Norway, showing the seven generators mentioned in the letter. Each generator is for 4100 kVA, 375 r/m, 25 p/s, 12,000 V. Cos φ = 0.9.

AKTIESELSKABET TYSSEFALDENE

Tyssedal, 22 Dec 1949
Hardanger

A/S Per Kure. Norsk Motor- & Dynamofabrik,
Postboks 101,
OSLO

Generators.
Our ref.: HJ/GS — file 47.

In 1908—1910 Asea delivered 7 generators, of 4,100 kVA and 12,000 V each, to the Tysse falls. After a few initial difficulties which necessitated rewinding of the machines, they all showed good results in service.

In 1916 we had a pipe-burst just behind the station which left the generator pits filled with water for a couple of hours. This caused insulation breakdown on four of the machines and 9 windings had to be replaced. On the other three machines the windings were unaffected. Since then, there have been no service interruptions of any kind.

The machines have now been in service with the same windings for about 210,000—240,000 hours. In this connection we wish to emphasize that they have not become any less reliable in the past few years though they have reached the number of service hours which is generally considered to be the total life of such a machine.

To help you to form an opinion of the conditions under which the machines have operated we will mention that they have never sustained any damage through short circuit of power lines. The number of such cases has, however, not been great as we are fortunately placed in this respect and lightning strikes very seldom occur. Line breakages have been caused by blasting. We have ample machine power, for which reason we have never had to overload our machines. We would estimate that they have been run at 0.8—0.9 of their normal capacity.

The maintenance, we consider, has been good. We have carried out the practice of not letting the machines go out of service for more than 14 days. After that time they have either been returned to service or run on short circuit for drying. They have been cleaned every 12—15 months, as service conditions allow. When we have found it necessary, we have lacquered the accessible parts of the windings.

We would be grateful if Asea from their great experience can give us information on whether — — — — — — — —

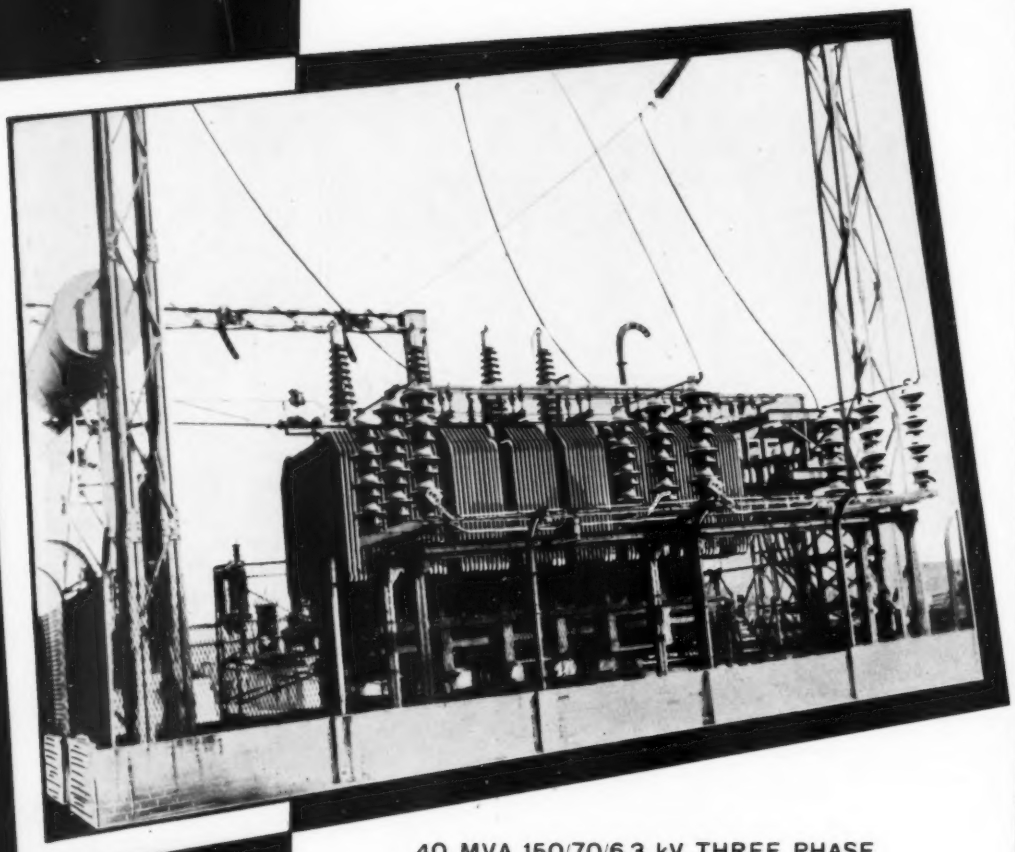
Yours faithfully
p.p. AKTIESELSKABET TYSSEFALDENE
(signed)

Translation of part of a letter from Aktieselskabet Tyssefaldene to Asea's affiliated company in Norway, A/S Per Kure.

ASEA

VÄSTERÅS - SWEDEN

All classes of electrical equipment for power stations and networks



40 MVA 150/70/6,3 kV THREE PHASE TRANSFORMER

Type RFR4 on load tap changing device on the HT side

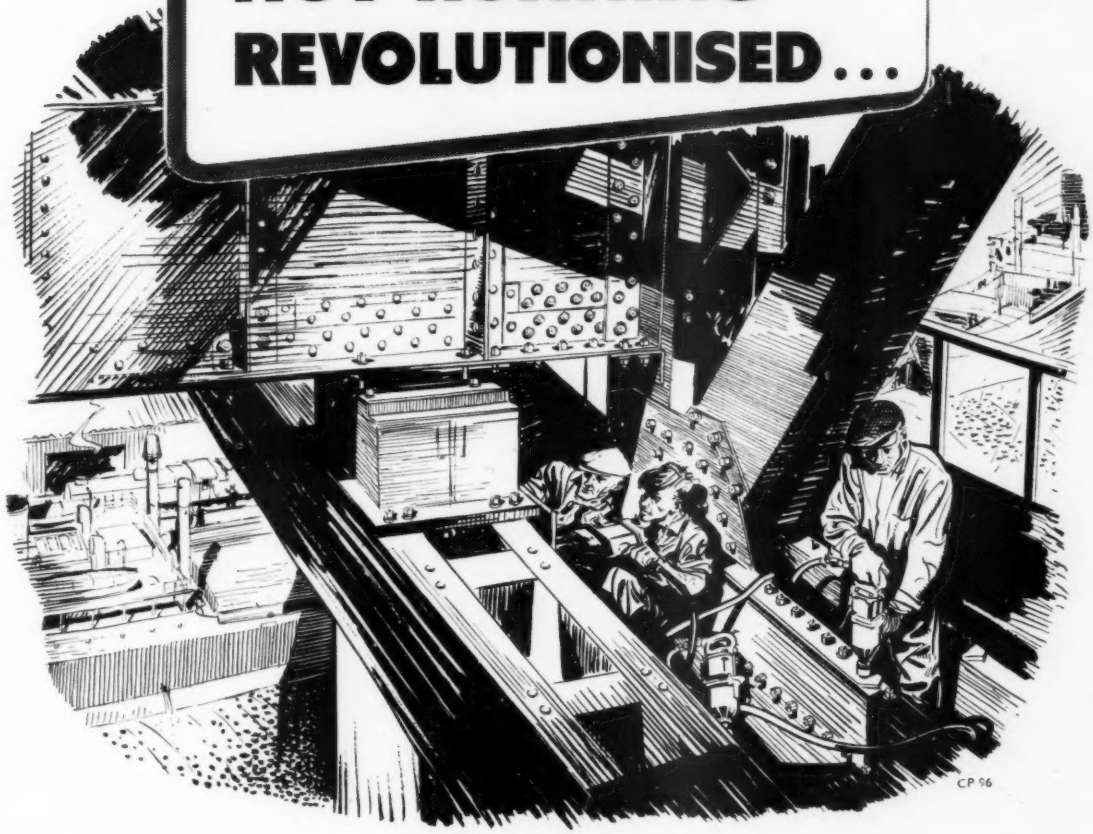
Installed at the Droogenbosch Power Station of the Union Intercommunale des Centrales Electriques du Brabant

Ateliers de Constructions Electriques de Charleroi

Charleroi · Belgium

CHARLEROI ACEC

NUT RUNNING REVOLUTIONISED...



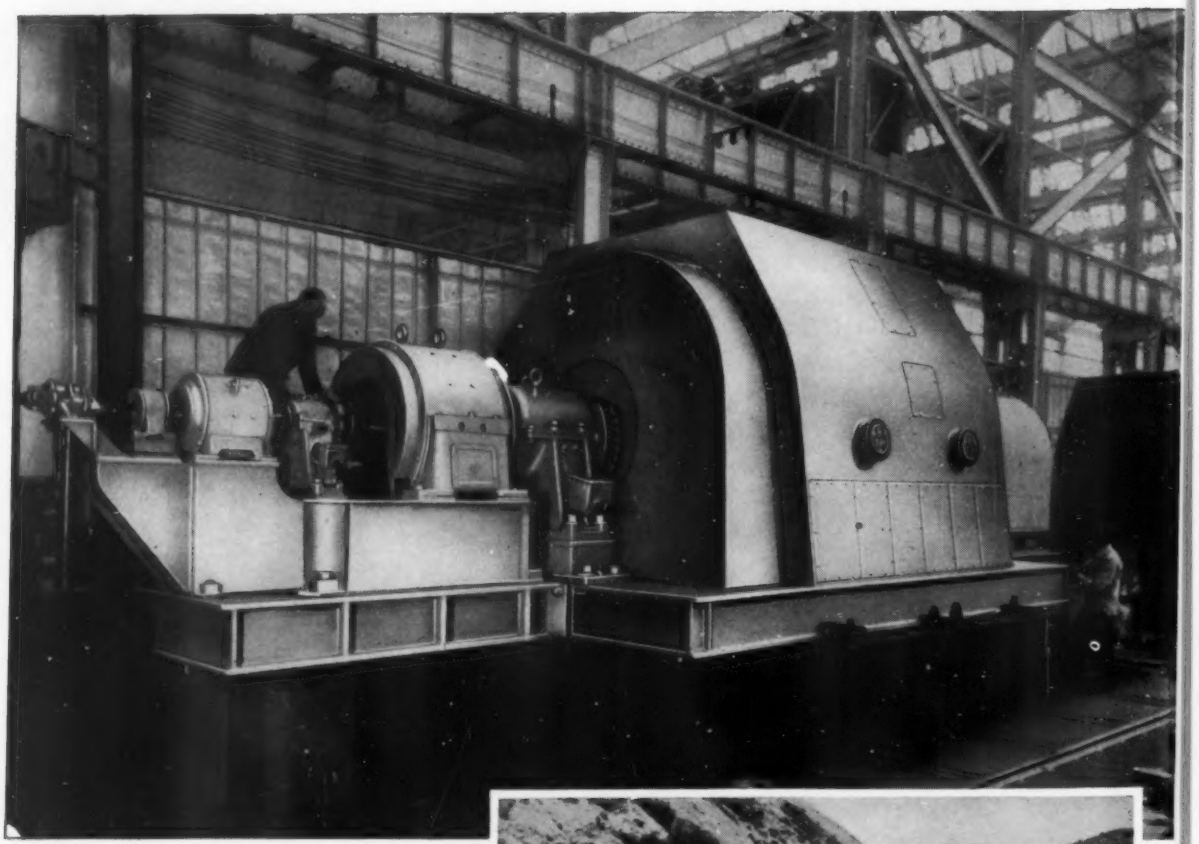
CP pneumatic impact wrenches are a truly revolutionary method for speeding operations involving all forms of nut running. They give to nut running a speed hitherto unknown and a tightness which defies hand wrenches even with great leverage. Yet, operated in reverse, CP wrenches loosen those same nuts quite effortlessly. On large construction jobs time taken is cut to a fraction. In plant maintenance the removal of seized nuts is simply accomplished without damage to either nut or bolt. Models are available for nuts of all types and sizes. To find out for yourself the amazing advances presented by this range of tools . . .

CALL IN CONSOLIDATED

CONSOLIDATED PNEUMATIC TOOL CO. LTD. - LONDON & FRASERBURGH

Offices at Glasgow · Newcastle · Manchester · Birmingham · Leeds · Bridgend · Belfast · Dublin · Johannesburg
Bombay · Melbourne · Paris · Rotterdam · Brussels · Milan · and principal cities throughout the world.

Hydro-electric Equipment



One of five 30,000 kVA., 750 r.p.m., 11,000 volt synchronous condensers supplied to the New Zealand State Hydro-electric Department. Two more are on order

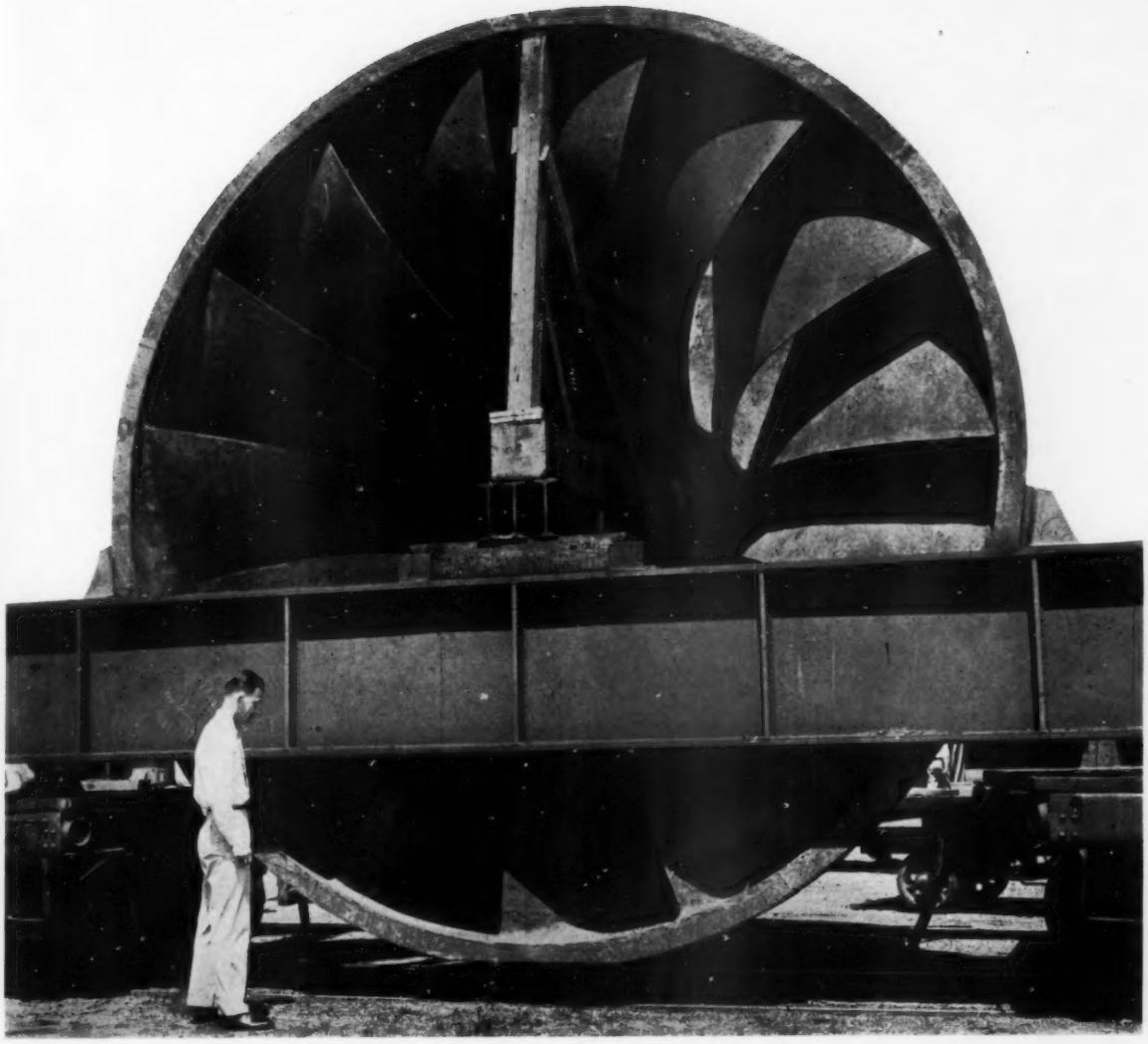
Stator of one of the above condensers during its journey in New Zealand from the docks to site.

For all plant required for
Hydro-electric Power Schemes
— Consult BTH

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO. LTD. RUGBY, ENGLAND

A3081



FACILITIES FOR THE SMALLEST OR LARGEST

The 225-acre Newport News plant includes plate steel and machine shops equipped with a complete variety of tools to fabricate items of water power equipment of any size. Contracts received by Newport News for hydraulic turbines with an aggregate rated output in excess of 7,000,000 horsepower have included units as high as 165,000 horsepower and as low as 500 horsepower.

Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

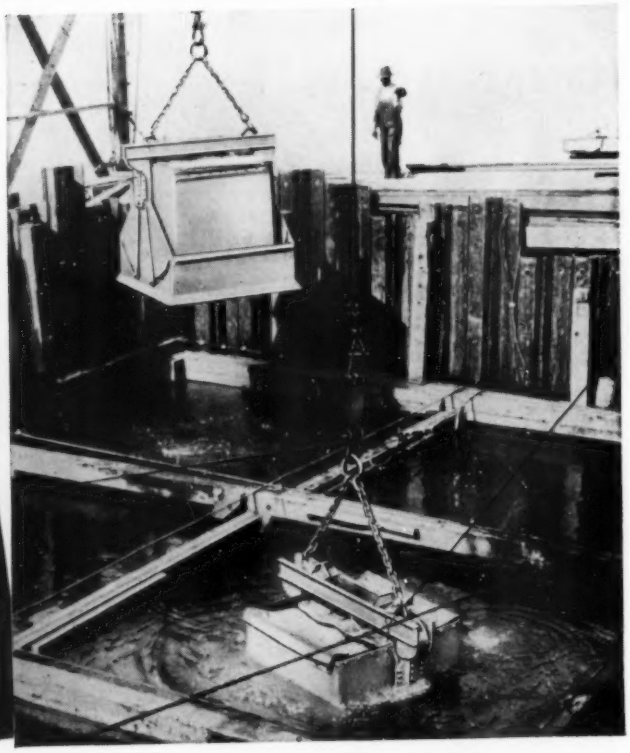
NEWPORT NEWS

SHIPBUILDING AND DRY DOCK CO.

NEWPORT NEWS, VIRGINIA, U.S.A.

UNDER-WATER CONCRETE PLACING

With accuracy and speed



The "TREMIE" Concrete Bucket for under-water concrete placing has been successfully used on many important projects, placing concrete in under-water positions as, for example, in dock and harbour construction and repair. The concrete, which is fully protected from swirling water, does not drop through water and does not displace water when being discharged.

There is a complete range of Blaw Knox Concrete Buckets . . . for every purpose and for big and small jobs. Write for publication BK-126 illustrating and describing, with data tables, the full range.

BLAW KNOX CONCRETE BUCKETS

BK-41

THERE'S A BLAW KNOX CONCRETE BUCKET FOR EVERY PURPOSE

"CLAMSHELL GATE" BUCKET

"ROLLER GATE" BUCKET

"TREMIE" UNDER-WATER BUCKET

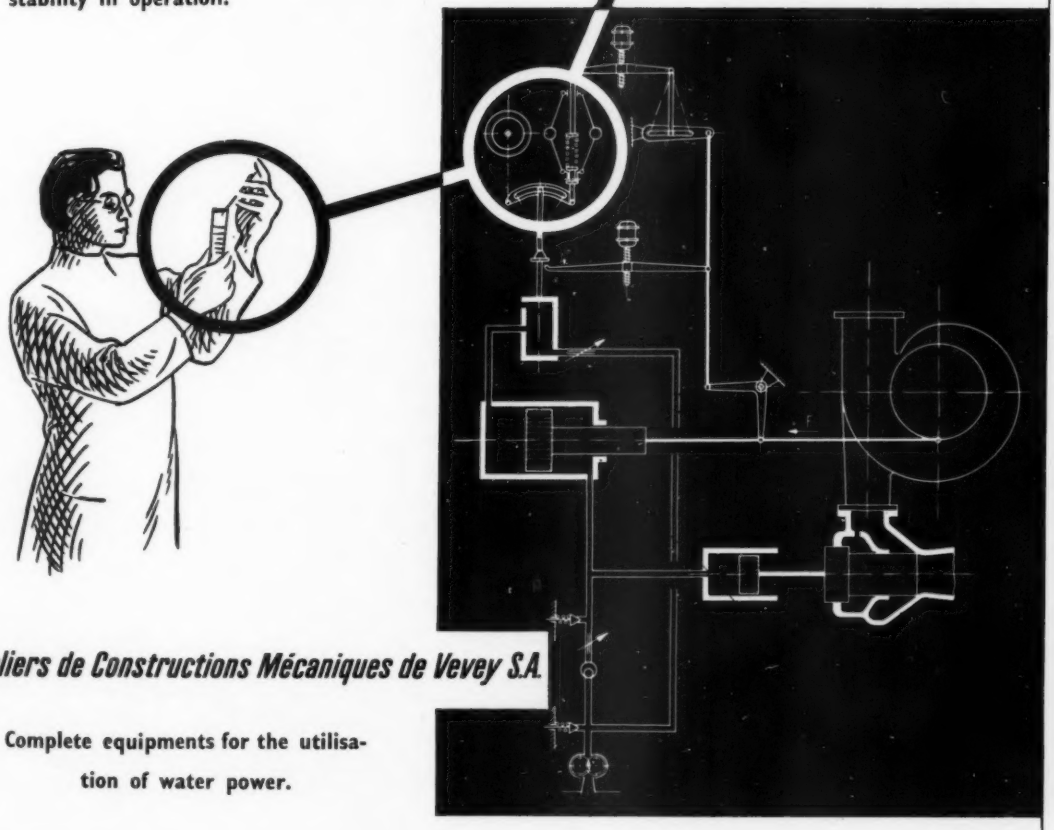
BATCHING, MIXING AND BULK CEMENT PLANT · CONCRETE MIXERS · HOTCMIXERS · CONCRETE PUMPS · CONCRETE SPREADERS AND FINISHERS
CONCRETE BUCKETS · STEEL SHUTTERING · ROADFORMS · DEWATERING PLANT · EXCAVATORS · LAND CLEARING EQUIPMENT · EARTH MOVING EQUIPMENT

BLAW KNOX LTD · 55 CLIFTON HOUSE · EUSTON ROAD · LONDON · EUSTON 5361

The Vevey speed governor

is the only one

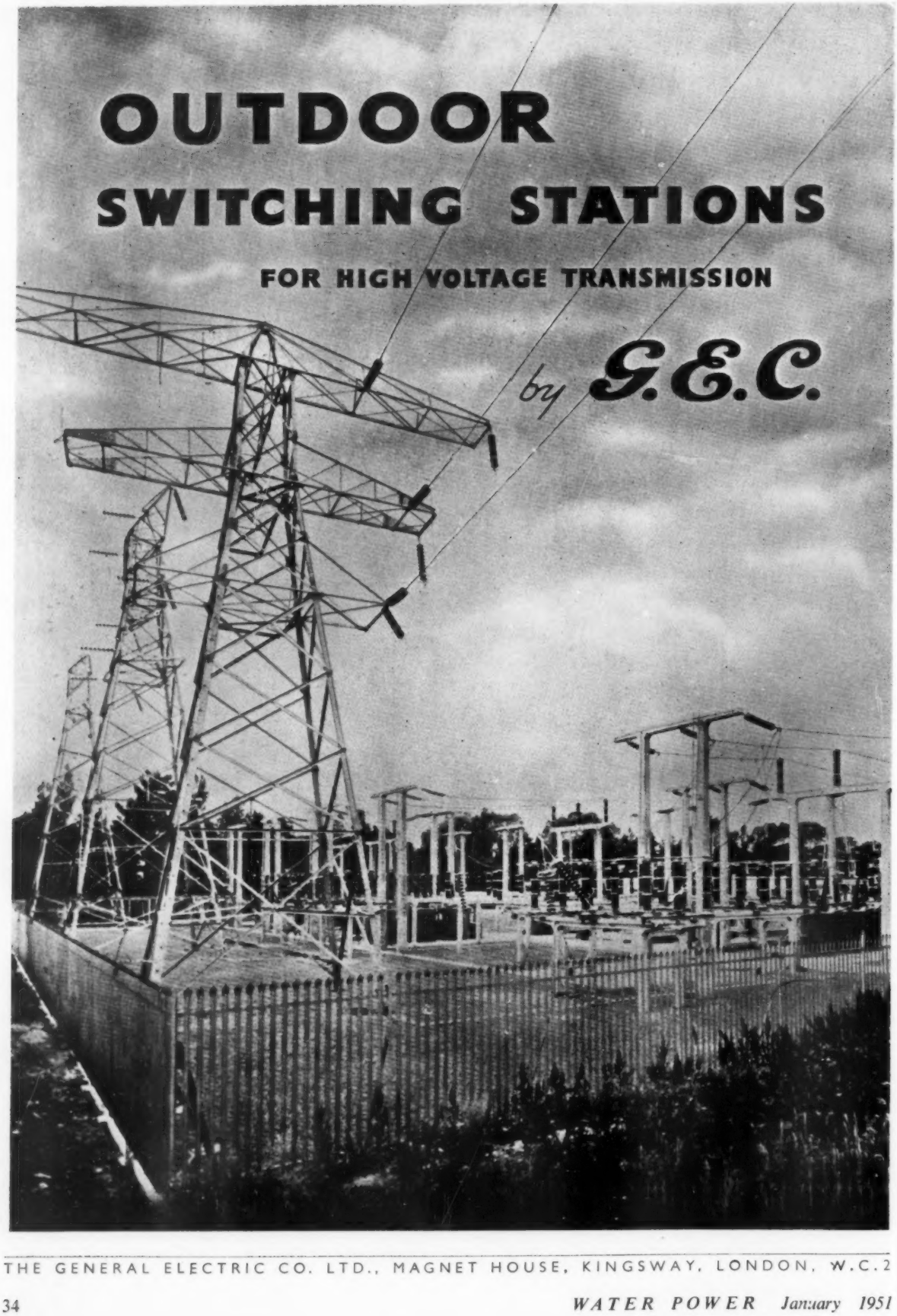
allowing an exact dosage during operation, of the effects of the accelerometer and tachometer.
This particular advantage makes this governor a modern engineering device by which extremely sensitive regulation can be obtained while at the same time ensuring the greatest stability in operation.



Ateliers de Constructions Mécaniques de Vevey S.A.

Complete equipments for the utilisation of water power.

1420



THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Order Your EUCLIDS Now!

● NOW BEING BUILT IN BRITAIN ● POWERED BY WORLD - FAMOUS CUMMINS DIESEL ENGINE ● AVAILABLE FOR STERLING ● DELIVERY 1951

EUCLID
THE PIONEER

The world-famous EUCLID Rear Dump Wagon, now available for STERLING, will be ready for delivery in 1951

PLACE YOUR ORDER NOW. ALL ORDERS WILL BE EXECUTED IN STRICT ROTATION

With a complete After Sales Service by the Sole Distributors:-

JOHN BLACKWOOD HODGE & CO. LTD

Sales :
11, BERKELEY STREET, LONDON, W.1.
Telephone : Mayfair 9514.

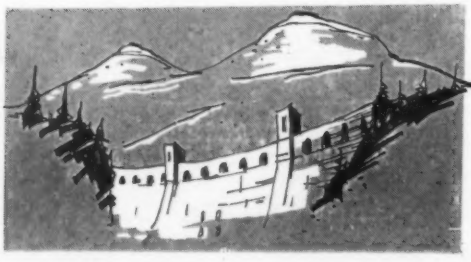
Works & Service :
HUNSBURY, NORTHAMPTON.
Telephone : Northampton 5262

U.S.A., EIRE, BELGIUM, PORTUGAL, SPAIN, SOUTH AFRICA, EAST AFRICA, WEST AFRICA, N. & S. RHODESIA, BELGIAN CONGO, MOZAMBIQUE, INDIA, PAKISTAN, CEYLON, BURMA, AUSTRALIA.

HARLAND - Morgan Smith water turbines

"Harland-Morgan Smith" Impulse, Francis, fixed and adjustable blade propellor type water turbines, in association with Harland generators incorporate the valuable research, design and practical experience of the famous S. Morgan Smith Company of the U.S.A., our own wide experience of hydraulic and electrical engineering, and the traditionally high quality of British workmanship.

The photograph above taken at our Alloa works during the final stages of shop assembly shows a 17,500 b.h.p. Vertical shaft, Francis turbine for the North of Scotland Hydro-Electric Board's Grudie Bridge Power Station, Fannich Scheme. The head cover, complete with wicket gates, is being lowered over the turbine shaft before securing to the stay ring.



THE HARLAND ENGINEERING COMPANY LIMITED
Works: ALLOA, SCOTLAND 'phone Alloa 390
LONDON OFFICE: HARLAND HOUSE, 20 PARK STREET, W.1
'Phone Grosvenor 1221
Overseas Agents in: AUSTRALIA, INDIA, MALAYA, NEW ZEALAND, PAKISTAN, ISRAEL, RHODESIA, SOUTH AFRICA and TRINIDAD

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Subscription Rates: 24s. Annually Post Free. Single Copies 2s.

VOLUME 3. NUMBER 1.

CONTENTS FOR JANUARY, 1951

Leading Article: Pakistan - - - - 1
Editorial Notes - - - - - - 2
Power Prospects in Pakistan - - - - 5
Development of Cumberland River Basin - - 8
The Study of Wave Motion - - - - 19
Tungsten-Carbide Drilling Bits - - - - 23
A Notable Water Tunnel - - - - 24
By C. F. Grundy, M.Eng., M.I.C.E.
Loch Sloy Control Equipment - - - - 31
Salmon and Hydro-Electric Operations - - - 32
Soil Tests for Earth Dams - - - - 33
By W. J. Turnbull and John L. McRae
From the Journals - - - - - 35
New Blaw Knox Excavator - - - - 39
A New Single-Tool Compressor - - - - 40

An index to WATER POWER for 1950 has been prepared, and is available free of charge on application to the publisher

Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

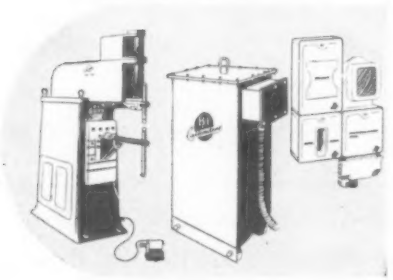
MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 81 Edmund Street. Telephone: Central 3049.
GLASGOW: 87 Union Street. Telephone: Central 4646.
NEWCASTLE-ON-TYNE: 21 Mosley Street.
LEEDS: 70 Albion Street. Telephone 27174

THIS B.I. Callender's IS THE SIGN . . .

for ***electric cables for working pressures up to 264,000 volts, and overhead transmission equipment.***

for ***every type of cable used in domestic and industrial installations — and wherever electricity is used.***

for ***a wide range of electrical accessories, and electrically operated equipment . . . fully listed in Publication No. 215D.***



. . . indeed, BICC are the World's largest manufacturing, marketing and contracting group concerned with electrical transmission and distribution, for power and telecommunications.

BRITISH INSULATED CALLENDER'S CABLES LIMITED
NORFOLK HOUSE, NORFOLK STREET, LONDON, W.C.2

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Pakistan

PAKISTAN, now India's neighbour in the development of the Indian sub-continent, is possibly more concerned than any other country of the world for its power developments over the next decade. This attitude is explained in the article contributed to this issue by our special correspondent, and the reasons for it are clear. Pakistan faces two primary, but opposite considerations regarding power development. First there is the acute shortage of natural fuels for generating electric power. Conversely, there is an abundance of water power potential which has been largely running to waste for ages. In such a situation the development of water power is undoubtedly wise, particularly as in this case the supply of energy can be combined with much needed extensions of the area cultivated by irrigation schemes.

As the newest independent member of the British Commonwealth, Pakistan has made great progress in the past three years. She has now balanced her budget, and has embarked upon schemes that must bring in their train considerable economic advances to a state sorely in need of them. The report of the United Kingdom Industrial Mission to Pakistan stresses three essential prerequisites for industrial development. First in order comes cheap and abundant power supplies; second, cheap and adequate transport; and third, a sufficiency of water supplies for irrigation as well as for power.

It was with the first of these that the mission was most deeply impressed, and their survey of the entire country led to the conclusion that, with the scarcity of natural fuel, the construction of hydro-electric undertakings rather than thermal installations is necessary for the country's economy. But the expansion of power supplies, in the view of the experts, is "vitally urgent"; so much so, indeed, that the mission regards as particularly important an immediate investigation of the water power resources to the west of Karachi, with the object of supplementing steam stations in that area, and, pending completion of that work, the supply by United Kingdom and other manufacturers of temporary plant.

Such, then, is the broad picture of Pakistan's needs. The field for trade in general, and the opportunities for the manufacturers of hydro-electric plant in particular, are distinctly promising. The mission emphasises one cardinal point to be borne in mind here—that of maintaining both close and constant touch with the country through local representatives. "Representation," it warns significantly, "can no longer be entrusted to firms which do not possess properly established offices in Pakistan. United Kingdom exporters should ensure that their agents have offices in the country, and these should preferably not be subject to the direction of other branches or agents in other parts of the Indian sub-continent." This is a clear indication of the changes in trading methods brought about by great political and economic changes. To overcome the additional expense which must inevitably be involved in the maintenance of these offices it is suggested that United Kingdom manufacturers of complementary products might consider the possibility of joint sales organisations, since the price of power plants, as in most other sections of export trade, is a fundamental factor in negotiating contracts.

Bearing these considerations in mind there is obvious point in the mission's statement that with a civil engineering field of abundant scope there should be a permanent "liaison" in London. A small administrative body from Pakistan, operating in the British capital as a link with the Pakistan Development Board in Karachi would be of great help in solving the many problems which must arise during the working out of plans for expansion.

The financing of both the hydro-electric projects and others envisaged for the improvement of Pakistan's economy has naturally been the subject of discussions and negotiations ever since the country became a separate State. Following the visit of the British Trade Mission, there has more recently been a prolonged tour of investigation by representatives of the World Bank for Reconstruction and Development. This tour, lasting several weeks, concluded only a few weeks before Christmas. The members, in consultation with Pakistan authorities, examined both the present state

of the country's economy, and the probable cost and effect of the schemes designed to raise the standard of living of the community. That their conclusions generally were satisfactory is clear from the opinion expressed by Mr. George Burgess, the leader of the Mission. When leaving Pakistan for India at the end of November, Mr. Burgess explained that he and his colleagues had investigated a wide range of individual projects for the development of power and industry. As a result he is of the opinion that these schemes will fit together into a constructive and well-conceived programme which will benefit greatly both the internal economy and the foreign trade of the country.

Since her advent to full statehood Pakistan has had to cope with unexpected difficulties from many directions, and only now is she beginning to emerge from them. Her appeal last year to the International Emergency Food Council for large quantities of grains to meet her immediate needs indicated a serious situation that, theoretically at all events, was out of the reckoning. But unexpected events bring unexpected results, and so the period of fierce internecine warfare which marked the creation of the new state led inevitably to the neglect of those vast agricultural areas which normally would have constituted the main source of supply. To these troubles nature added her own, as often is the case in the great sub-continent, with drought, floods and insect plagues. In such circumstances the vigour with which the Government of Pakistan has got to work during the past year in preparing its plans for recovery and advancement must be counted an excellent sign for the future. She has shown and, as reports indicate, independent observers and investigators share the view—that her difficulties, though considerable, are not insurmountable, providing there is no major world upheaval during the next decade.

Papuan Survey

NEW GUINEA, biggest island in the Pacific Ocean after Australia, may quite possibly follow her great neighbour in seeking to harness the latent power of rivers now running to waste. Completion of an important survey in the Papuan area is reported officially from Australia. The final stage was finished last November by Mr. C. I. Viccars, who represents a large firm of British consulting engineers. He flew from Port Moresby to undertake a complete aerial survey of the falls and rivers in Western Papua to determine the large potential forces for the supply of cheap hydro-electric power in the territory. Mr. Viccars is technical adviser to the New Guinea Resource Prospecting Company.

Norway's Growing Industry

THE industrial progress of Norway, most marked since the end of the war, is stated officially to be due in no small measure to the continued development of the hydro-electric resources of the country. Provisional figures published by the Central Statistical Office in Oslo show that the gross value of Norwegian industrial production last year was £362½ million compared with £341¾ million in 1948 and the number of industrial concerns employing five people or more was 6,086, against 5,956 in 1948. Hours worked in industry totalled 439 million, compared with 421 million in 1948. The expansion of hydro-electric resources over the last five years is indicated by the fact that from 1945 to 1949 the amount of electricity produced each year has gone up from 10,000 million kWh to over 16,000 million kWh.

Canadian Schemes

IN a note on the British Columbia Electric Company's hydro-electric development at Bridge River it was mentioned that this scheme would ultimately be the largest in Canada "with the exception of the St. Lawrence River projects." The actual phrasing of the paragraph however made it appear to some readers that the Bridge River undertaking would be the largest in the Dominion. This, of course, is not so, and literally was not so stated. For example, Shipshaw No. 2, the Aluminium Company's plant on the Saguenay River, has a capacity of 1,200,000 h.p. in one plant, and the Quebec Commission's Beauharnois plant on the St. Lawrence, will eventually develop up to 2 million h.p.—a point covered by the reference to the exception.

Looking for Labour

IN pursuit of their extensive hydro-electric schemes the Tasmanian Hydro-Electric Commission is looking to both Britain and America for workers. In the past few months the commission has sent two officers overseas to recruit labour and study industrial processes. The Commission's industrial officer, Mr. C. Best, has visited the United Kingdom in a search for construction experts and others to assist in the island's power development projects, and Mr. K. Davidson, an electrical engineer, has spent some weeks in the United States on a similar search.

Hydro-Electric Films

UNDER the aegis of Enfield Cables Limited three interesting films were exhibited in Wardour Street relating to various aspects of hydro-electric power generation and distribution. The first of these, Eternal Power, pictured the development of the hydro-electric resources of Switzerland; in 1948 this small country generated 2,250 kWh per head of population—more than any country excepting Norway and Canada. The process still continues, the aim of more recent developments being to create high-level water storages in the mountains to afford reservoirs of energy when frost inhibits the flow from the snowfields. The second film dealt with the 600 mile 380 kV transmission line constructed by the Swedish Electric Power Board to carry energy from the Arctic Circle to the centres of population in the south. The line has necessarily had to be erected along an uninhabited tract of forest and swamps, and its construction provides a story of dramatic interest and high endeavour.

Shipshaw, the world's largest aluminium plant at Arvida, Quebec, formed the subject of the third film. This station, which has an installed capacity of 1,200,000 kW was built within a period of two years during the recent war to provide aluminium for the

Allied forces. It now has an output of 2,000,000 lb. every 24 hours and the film portrays the construction of the dam, station and power house.

High Voltage Tests for Switchgear

AT Stafford, a gathering of engineers from Great Britain, the Dominions and oversea countries attended a demonstration at The English Electric Company's Nelson Research Laboratories, in which switchgear for voltages up to 400 kV was seen on test. To hydro-electric engineers the significance of this lies in the fact that the manufacturers of electrical equipment realise that the utilisation of remote hydro-electric resources may involve very lengthy transmission lines; and this in turn involves higher voltages than those at present used. In Sweden, a 380 kV transmission line is under construction, and will be the first in the world. Others are likely to follow, and the demonstration at Stafford showed that switchgear designers, at least, are ready with the equipment for further lines when they are needed.

The particular type of circuit breakers seen on this occasion were of the airblast pattern, and were designed so that a standard interrupter unit could be adapted, by being built up in various combinations, for any voltage likely to be required. For instance, for 132 kV, two interrupters in series are used, and for 400 kV, eight are assembled in series, in two columns, which are themselves connected in series with an auxiliary isolator interposed between the two.

The testing of high voltage, heavy duty switchgear has become, in these days, beyond the capacity of any one testing station, and engineers concerned with high voltages are generally agreed that it is now sound practice to test individual units of this type at full voltage and power, and then to test the completed unit at full voltage low current, and full current low voltage. The results of extensive "artificial tests" of this nature have proved that they may be entirely relied upon to show that the full-scale unit will carry out its designed function when installed on the system.

A novel feature of the demonstration was the fact that television was used extensively to give close-up views of the breakers under test, and further enabled the engineers to demonstrate all the test results, by diagrams and oscillograms, so that each member of the large audience was able to follow the tests with the utmost clarity.

Eildon Dam in Australia

IN OCTOBER 1949 the State Electricity Commission of Victoria and the State Rivers and Water Supply Commission commenced investigation of a proposal to raise the Eildon Weir, situated on the River Goulburn, sixty miles north of Melbourne, 12 ft. higher than the enlargement plan recently approved by the Cabinet. This proposal would raise the holding capacity to 2,750,000 acre feet, thereby increasing the amount of energy which would be generated. In April 1950, tenders were called for the construction of Big Eildon Dam, with 13,000,000 cu. yds. earth and rock fill, 200,000 cu. yds. concrete, outlet and control works, pondage weir and all associated works.

The Victoria Government in August accepted the tender of the Utah Construction Company of the United States to build the great new Eildon Dam for £A11,360,000 (£9,088,000 sterling). The Utah Construction Company's tender beat eight others, four of them British, two American, one American-Australian and one New Zealand. Victoria's water commission chairman said the most advantageous British tender was a million pounds more and 16 months longer. The British tenders came from John Howard & Co., Keir & Cawder, Sir Lindsay Parkinson, and Wimpeys & Son.

Power Speed-up by Steel

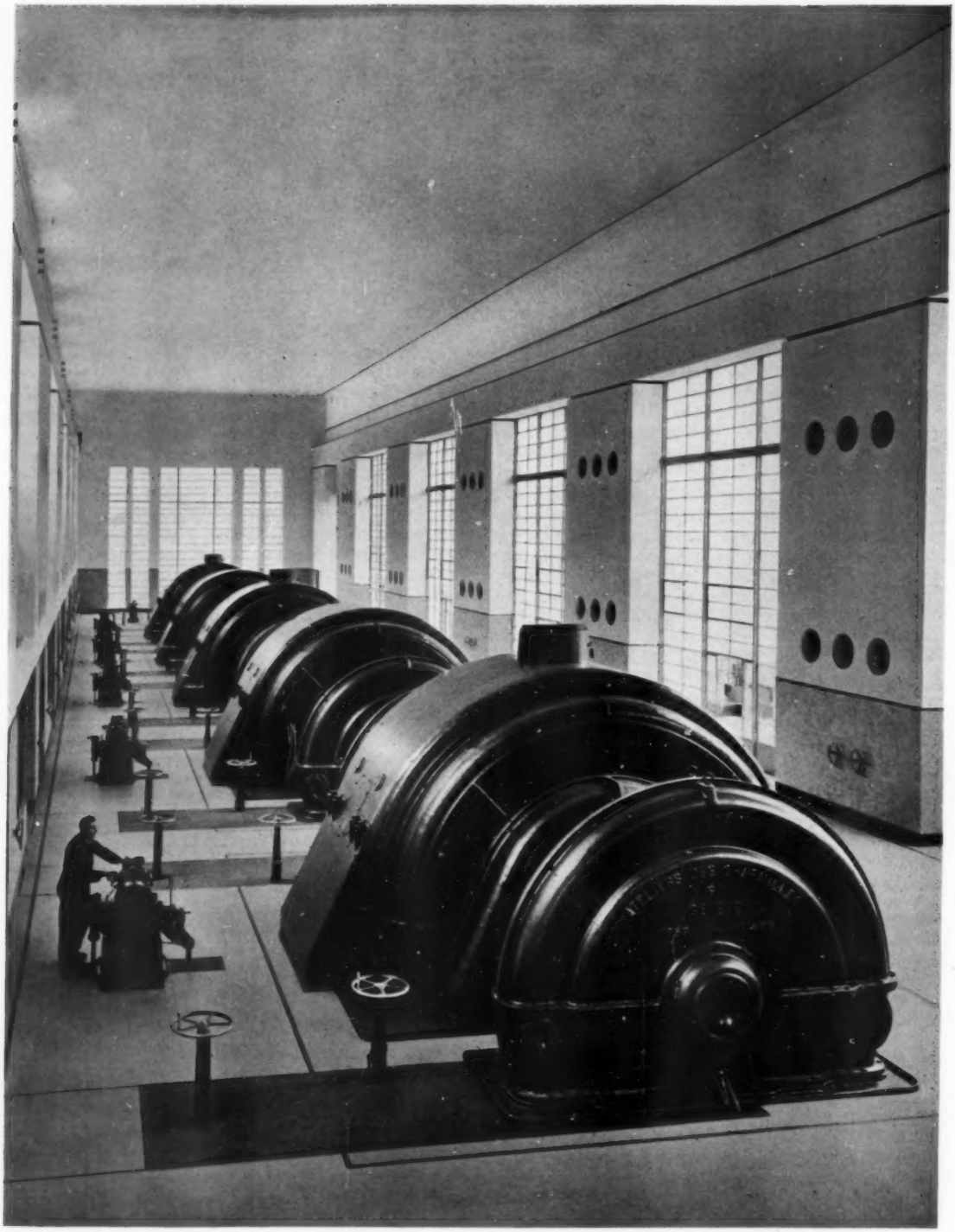
THE Pacific Northwest has been growing faster than its electric power capacity. However, a simple design change in one hydro-electrical power project may turn the region's power-famine into a power-feast. As stated in a report in *Business Week*, the Bureau of Reclamation recently agreed to change the design of its powerhouse at the big Hungry Horse dam project in Montana from a reinforced-concrete to a steel frame structure. This one change — at an extra cost of $155,000 — is calculated to give the Pacific Northwest 125,000 kW of capacity a whole year earlier than originally planned.

A steel-frame building can be put up faster because the work can be done year-round; reinforced-concrete work would be interrupted by winter. As soon as the frame is up, travelling cranes can be mounted. Only then can the turbines and later the generators be installed. Working over next winter, the contractor will be able to mount two 290-ton cranes in the Hungry Horse powerhouse by July, 1951. By October, 1952, the first generator should be operating. The $43,431,000 construction contract calls for the water storage dam to be in operation in 1951.

Power Increase from Niagara Falls

A NEW Niagara River water treaty, revising a 41-year-old one, has been signed by United States and Canadian authorities. The new treaty has still to be ratified. The new plan proposes a $300 million re-development which promises more than three times the power now produced from the Falls. Terms of the new treaty reallocate water between the two nations, calling for a fifty-fifty sharing of that available for power use. The earlier treaty had given Canada a larger share.

Despite the important role of power in the new treaty, it provides for an adequate flow over the Falls to preserve the scenic spectacle. From April 1 to September 15 each year, flow over the Falls will be maintained at not less than 100,000 cu. ft. per sec. from 8 a.m. to 9 p.m. From September 12 through October 31, the required flow during these hours need be only 50,000 cu. ft. per sec., but this may be increased for flushing ice. In addition, the treaty provides for the construction of remedial works to ensure an unbroken crestline at the Falls.



Dixence Power Station, built by the Société l'Energie de l'Ouest-Suisse, has the highest drop used in the world—5,470 ft. The plant consists of five units each consisting of two single-jet Pelton turbines disposed on either side of a 37,500 kVA, 13 kV three-phase alternator

Power Prospects in Pakistan

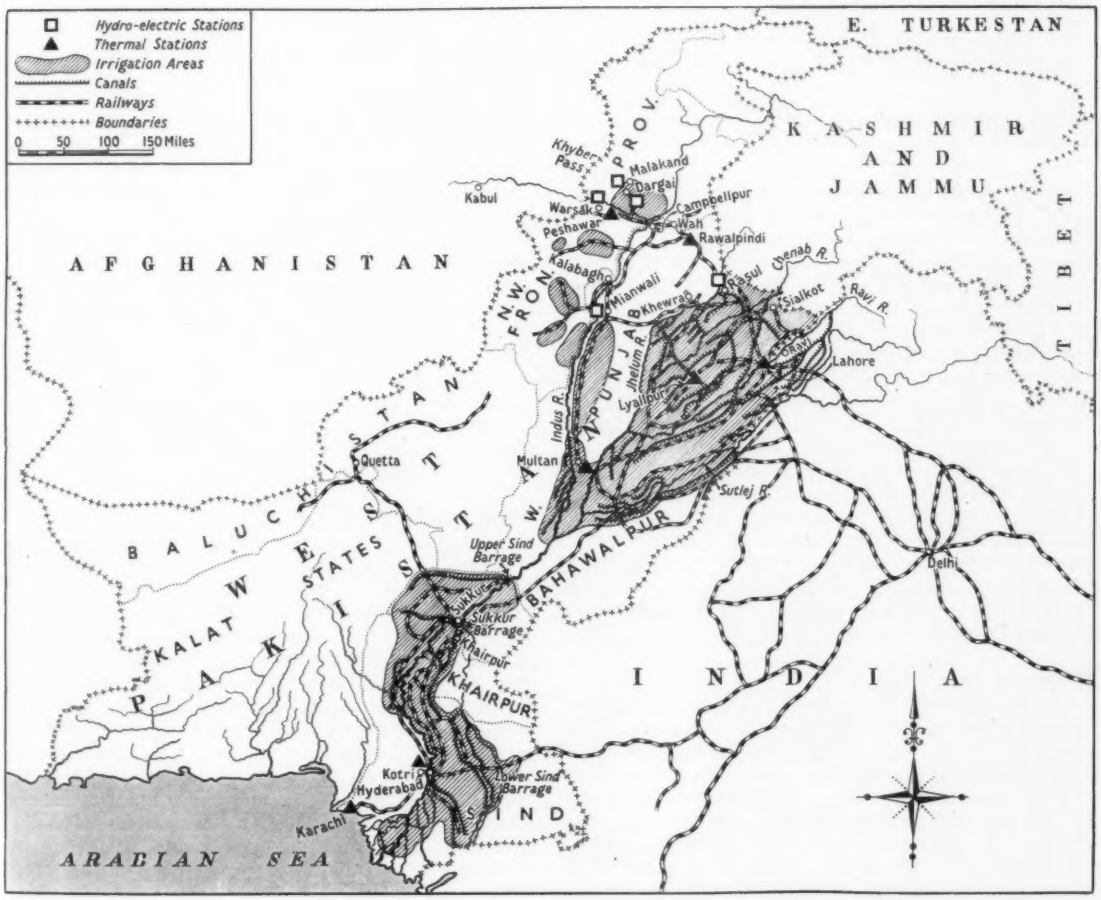
A special correspondent discusses the recently published report of the United Kingdom Industries Mission to Pakistan in relation to hydro-electric power generation

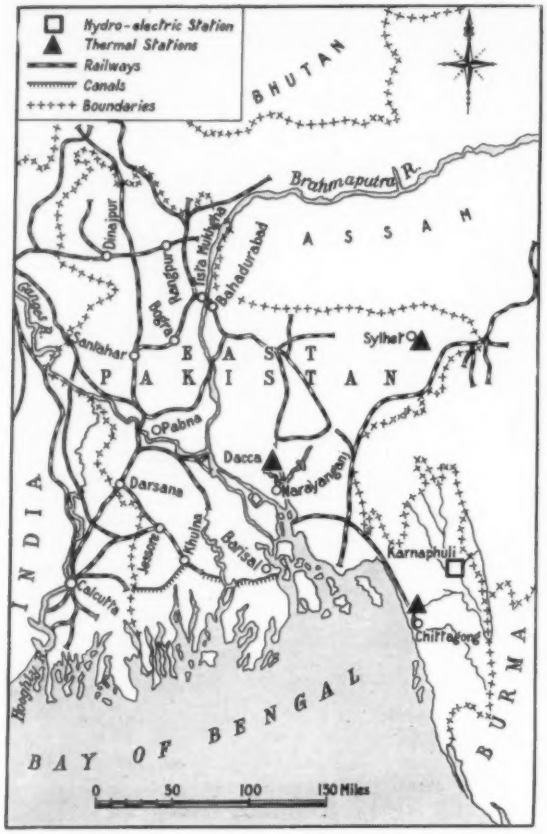
THE rapid expansion of power supplies is of paramount importance to the economic future of Pakistan, the new State comprising extensive areas formerly included in north-east and north-west India, but now a separate country. This is one of the main conclusions reached by the United Kingdom Industrial Mission after a survey of the territory in the past year. The mission believes also that this field is a most promising one both for direct stimulation of trade between this country and Pakistan during the period of development, and for the employment of British resources to assist Pakistan in the planning and execution of development schemes.

A cardinal point of the lengthy report published by the Stationery Office (7s. net) is that a plentiful supply of cheap electrical energy in strategic locations must be an essential feature of any economic scheme for the industrial future of Pakistan. Lack of power and deficiencies in water supplies are two of the principal factors hampering industrial development today. Apart from the needs of ordinary services and industries, power also is required urgently for dewatering the waterlogged areas which are spreading year by year around the main unlined irrigation canals at an alarming rate.

Fuel Scarcity

Another consideration is that Pakistan suffers from a shortage of natural fuel, thus making the utilisation of hydro-electric power of greater urgency than otherwise would be necessary. The report declares, in fact, that despite the great distances between the sources of water power and some of the more industrial areas, such as Karachi, " it would appear that the long-term development of the considerable hydro-electric resources, rather than thermal power," affords the





readiest means of promoting the country's economy.

In the approach to prospective power schemes the Pakistan Government has appointed as advisers two prominent British firms of consulting engineers, Messrs. Merz and McLellan (electrical and mechanical engineers) and Messrs. Rendel, Palmer and Tritton (civil engineers) together with the latter firm's associates on hydro-electric work, Messrs. Vattenbyggnadsbryan, of Stockholm. This combination, known as Messrs. Merz Rendel, Vatten (Pakistan)—abbreviated to M.R.V.P.—is preparing the general scheme for power development. It has surveyed existing thermal power stations in West and East Pakistan and is now engaged on a load survey of the entire country. Exploration work by shafts, headings and boreholes into the river beds is also proceeding to prove the foundations of the dams for two major water-power projects, one at Warsak, in the North-West Frontier Province, and the other at Karnaphuli, in East Pakistan.

Extension Plans

At the time of the mission's visit the only water power plant in commercial operation was at Malakand (N.W.F.P.) with an installed capacity of 9,600 kW. Extensions for a further two 5,000 kW sets are well advanced, and it is expected that the units will be in operation within the next few months. The Rasul water power plant, with an installed capacity of 22,000 kW now under construction, should be completed by the end of this year, and the Dargai scheme (installed capacity 20,000 kW) in 1953. The new hydro-electric projects at Mianwali, Karnaphuli and Warsak, with installed capacities respectively of 20,000, 40,000 and 105,000 kW have been assumed to be ready for operation in 1954, 1955 and 1956. These schemes, together with others — not hydro-electric — envisaged by the government, represent expenditure amounting to something like £50 million, and thus form a substantial part of the plans scheduled as necessary for the immediate development of the country.

In addition to these three schemes there are already in various stages of construction other important works. Of these, already briefly enumerated above, the Rasul scheme in the Punjab will cost approximately £3 million. The work here, consisting of headworks on the Upper Jhelum Canal, a headrace channel, forebay, power station and tail race channel returning the water to the Lower Jhelum Canal, was begun five years ago. At the time of partition, however, the orders for steel penstocks and lining were held up, and considerable delays and extra costs have inevitably resulted. The water turbines and electrical equipment from the United Kingdom have been stored on the site for about two years, but it is now anticipated that the first set should be in commercial operation during the present year.

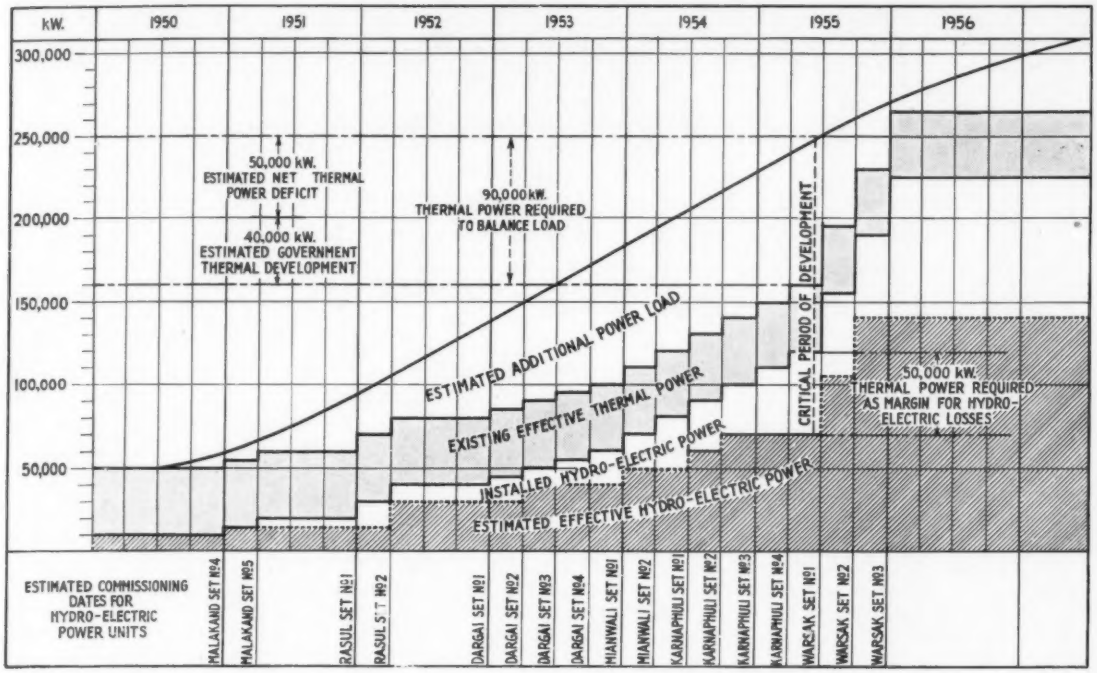
Malakand and Dargai

The much smaller Malakand scheme (approximate cost £200,000) is really an extension of an existing water power station completed 17 years ago with an installed capacity of three sets totalling 9,600 kW. Water is taken from the River Swat to the power station forebay, and through steel penstocks provides a gross head of 250 ft. on the turbines. The extension here consists of two 5,000 kW sets, and the civil engineering work is now ready for the installation of machinery. The first turbine was shipped from the United Kingdom last March and it is hoped the station will be in commission by the end of the year.

The £2 million Dargai scheme relies on the utilisation of the Malakand station tail race water which is passed through a four-mile canal to the forebay. Here again, steel penstocks provide a gross head of 250 ft., and the tail race water is returned to the irrigation canals. Installed capacity is to be four 5,000 kW sets to be supplied from the United States. The work, begun in April, 1949, is expected to be completed by the end of this year.

Transmission Problems

Regarding the country's power problems in general, it is pointed out in the report that although conditions in both West and East Pakistan are similar as far as generating is concerned, the problem of transmission of the energy from the schemes at present in hand or contemplated are markedly different in the two sections. In West Pakistan, as the accompanying map illustrates, there is no immediate call for power in any great quantity south of Multan, except for the area around Karachi. Consequently, the Government programme for the present seeks to develop the water power resources of the North-West Frontier and Punjab provinces only. Karachi, 600 to 800 miles away, must therefore remain, at any rate for some time, a thermal station area, as the costs of transmission at present would appear to be prohibitive.



The mission suggests, however, that the water power resources of the rivers to the west of Karachi in the Kalat and Las Bela states might be investigated with a view to operating one or more hydro-electric stations in conjunction with Karachi's thermal power development. It adds: "If this does not materialise there would appear to be no alternative, other considerations apart, but to establish heavy industries as far as practicable in the Peshawar and Lahore areas, where ultimately hydro-electric power will be readily available." In East Pakistan, on the other hand, the water power station is near the centres of consumption, and transmission problems are not likely to be serious.

Growing Consumer Demand

On the consumption side it is estimated that the demand from all users of electrical energy will have grown to 250,000 kW during the next five years. Thus, in order to provide a margin for load factors, breakdowns, standby and seasonal losses, the aim should be to complete the immediate part of the development plan, namely 300,000 kW, in five years also. "We believe," the report adds, "that British engineers, contractors, and manufacturers can greatly assist the Pakistan Government to do so."

For this five-year plan a three-stage development scheme is put forward. The required expansion, it is suggested, may be achieved over this period by the employment, first, of temporary semi-mobile, diesel-driven sets, followed by the establishment of permanent steam stations which would function at full capacity pending the commissioning of hydro-electric units towards the end of the development period. This programme is timed on the assumption that the period from the date of initiating the design by the consulting engineers to the date of commissioning is approximately as follows for the three classes of development:

Diesel stations -	- 12—30 months
Steam stations -	- 30—48 months
Water power stations -	48 months

British Equipment

"Since our return from Pakistan," the authors of the report state, "some enquiries have been made from British plant manufacturers regarding the most readily available types of generating sets for the purpose. The replies are encouraging in so far as the sets suggested by the manufacturers are, in our opinion, admirably suited to the requirements of the development outlined. The diesel driven units are self-contained generators ranging from 250 kW to 1,000 kW capacity and the steam sets are 5,000 kW turbo-alternators with twin oil-fired bodies of 35,000 lb. per hour rating at 400 lb. per sq. in. steam pressure and 750°F. superheat. Sets similar to the steam generators are, in fact, now being installed in the extension of the Karachi Power Station."

Three Stages

The first stage of development is conceived to be the installation of the diesel sets adjacent to, or actually inside, the industrial factories. This will be followed by the construction of the steam stations, strategically sited near the centre of gravity of the load. Later, when hydro-electric power is available, the reasonably mobile diesel units can be dismantled and removed to more remote areas to operate in advance of the spread of transmission network. In general it is a conclusion of the mission that for factory conditions as usually known, hydro power must be supplemented by steam generating to meet the characteristics of continuous factory production

Continued on page 18

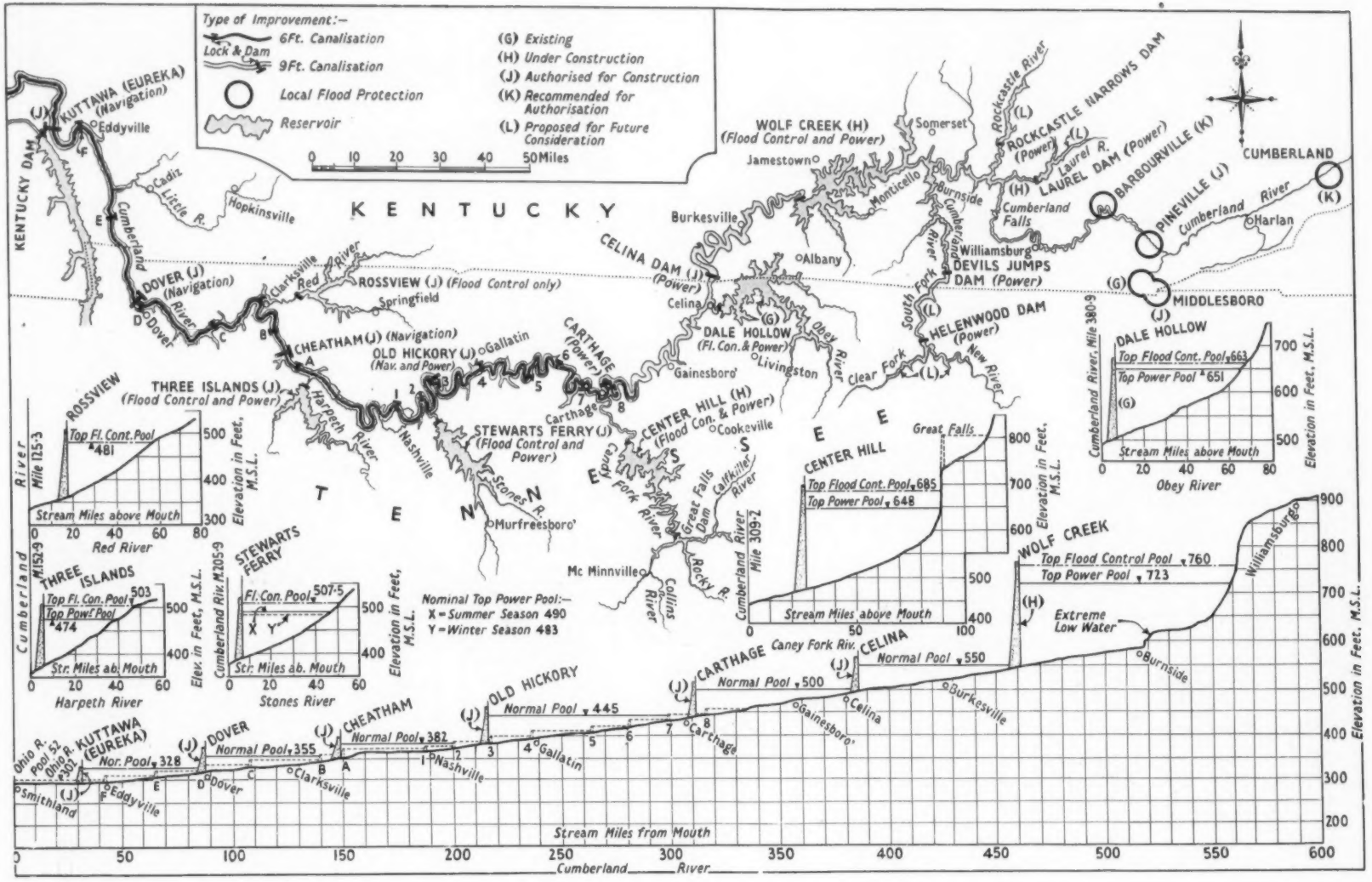


Fig. 1. Map of Cumberland River Basin and its tributaries showing plan of development

Development of Cumberland River Basin

GEORGE D. BINGHAM describes the hydro-electric development of the Cumberland River, one of the main tributaries of the Ohio, as planned by the United States Corps of Engineers.

Ce projet de grands travaux a pour but ultime la production de 2 milliards 900 millions de kwh par an; mais d'autres bienfaits également importants résulteront de l'aménagement du bassin: l'agriculture sera préservée du fléau des inondations et les plans d'irrigation pourront être mis en oeuvre. Le plan d'ensemble envisage la construction de douze projets différents: trois, à buts multiples, trois, purement hydro-électriques et trois, enfin, destinés à faciliter la navigation. Quatre autres projets, dans le bassin supérieur du fleuve, seront étudiés à nouveau.

Este proyecto ha sido ideado para la producción eventual de 2.902 millones de kWh por año, pero se lograrán resultados de importancia igualmente satisfactorios del control de inundaciones, el cual será de ayuda para la agricultura, impidiendo inundaciones destructoras y fomentando proyectos de riego. Esta obra abarca la construcción de doce proyectos, seis de los cuales serán proyectos para fines múltiples; tres de estos proyectos estarán exclusivamente destinados al suministro de energía, mientras que los tres restantes serán diseñados para ayudar la navegación.

THE major undeveloped hydro-electric power potential of the eastern United States is being effectively harnessed as the Nashville, Tennessee, District of the Corps of Engineers, Department of the Army, continues development of the water resources of the Cumberland River Basin under the direction of Colonel A. W. Pence. To be completed at a cost of $344,170,000, the programme is designed for an annual output of 2,902 million kilowatt hours, in addition to the tangible and intangible benefits derived from such factors as flood control, navigation, stream-pollution abatement and recreation.

The Cumberland River, one of the principal tributaries of the Ohio, is located entirely within the States of Kentucky and Tennessee; its basin, with an average width of about 50 miles and an axial length of approximately 350 miles, has a total area of 17,720 square miles. The topography of the basin varies from rugged mountains in the eastern portion to a rolling low plateau in the western part, with elevations ranging from 4,150 ft. above mean sea level in the Cumberland Mountains to 302 ft. in the pool water at its confluence with the Ohio.

The entire length of the stream is 693 miles, and the total fall about 842 ft. The Cumberland is a clear-water stream, carrying relatively small amounts of suspended matter except at flood stage. The normal annual precipitation in the basin is approximately 51 in.

The river has long contributed to the economic advancement of the area it serves. Nashville, the capital of Tennessee, received its first white settlers from riverborne raft in 1790. Some half a century later the people of this fertile river valley began to realise the importance of the Cumberland River in the development of a region so rich in agricultural, mineral and industrial potential and made initial appropriations for a survey and improvement of certain sections of the stream. As the river began to take a place of national importance, in 1870 and 1875, Congress authorised further surveys. Construction of the initial projects for navigation improvement were based on these surveys. The inadequacy of this single purpose improvement plan was apparent, however, in the early 1930's, and the Corps of Engineers was later authorised by Congress to study a comprehensive plan involving the following considerations:

The control of floodwaters for the benefit of the Cumberland, Ohio and Mississippi River valleys;

Adequate navigation facilities to meet present and prospective requirements;

Development of the large hydro-electric power potentials;

The abatement of pollution and the creation of wild-life refuges and recreational facilities which incidentally result from construction of reservoirs for other major purposes.

The present plan for the development of the Cumberland River was approved by Congress in 1946 which integrated previously authorised flood-control projects into a comprehensive plan. This plan, as approved, provides for the effective utilisation of all the water resources, and will be secured by the construction of twelve projects with four additional projects which will be brought forward for further investigation when the needs of the valley so dictate.

Exploitation of the hydro power potential of the valley, the control of devastating floods and the improvement of navigation facilities all received major consideration in this plan. The projects in the

Fig. 1. Map of Cumberland River Basin and its tributaries showing plan of development

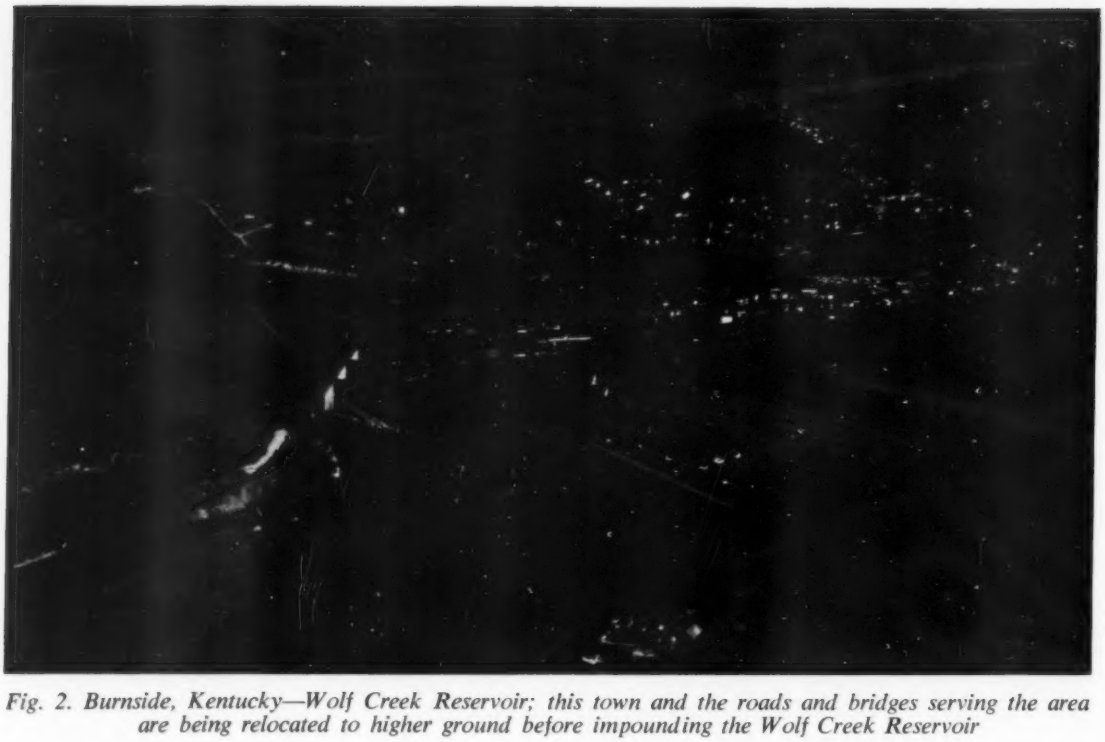


Fig. 2. Burnside, Kentucky—Wolf Creek Reservoir; this town and the roads and bridges serving the area are being relocated to higher ground before impounding the Wolf Creek Reservoir

authorised plan may be divided into four groups:

(1) Six multi-purpose projects.
(2) Three Upper Cumberland River main power projects.
(3) Three Lower Cumberland River navigation projects.
(4) Four possible projects in the extreme headwater region.

All projects in the first three groups have received Congressional authorisation for construction; the remaining four are in the long-range plans of the Corps of Engineers and will be submitted for approval only if conditions at that time make their construction economically feasible. Projects in group 1 include Wolf Creek Dam on the Upper Cumberland's main stem, Dale Hollow Dam on the Obey River, Center Hill Dam on the Caney Fork River, Stewart's Ferry Dam on Stone's River, Three Islands Dam on the Harpeth River, and Rossview Dam on Red River. These projects are primarily for flood control and hydro-electric power production.

Power will be produced at each, with the exception of the Rossview project where geological conditions are not conducive to efficient hydro-electric development.

The group 2 projects are primarily for power production with provision for navigation facilities if traffic warrants. These projects are all located on the

Fig. 3. Burnside, Kentucky, Relocations—Wolf Creek Reservoir; view of the substructure of U.S. Highway 57 showing bridge in foreground and Southern Railway bridge in centre; clearing line is visible in background

main stem of the Cumberland and are designated as Old Hickory, Carthage and Celina projects.

The three projects in group 3 are primarily for navigation improvement. These projects—Cheatham, Dover and Kuttawa (Eureka)—will be located on the main stem between Nashville and the mouth of the river.

Dale Hollow Dam, first of the six multi-purpose projects to be constructed, was completed for flood control purposes in 1943, and the powerhouse was put into operation in 1948. The dam is an all-concrete structure, 1,717 ft. in length with a maximum height of 185 ft. This reservoir, with a total storage capacity of 1,706,000 acre-feet, controls the run-offs from the Obey River, one of the major tributaries to the Cumberland. Since being put into commission, this project alone has been effective in reducing flood crests of several floods at Nashville and below. The Morrison-Knudson Company of Boise, Idaho, constructed this dam in the record time of 16 months.

The powerhouse at this project contains two 18,000 kW generators and will produce an average annual energy output of 120 million kWh. Provisions are also made at this plant for the installation of a third 18,000 kW generator to provide an ultimate rated plant capacity of 54,000 kW. The powerhouse was also constructed by the Morrison-Knudson Company.

The Center Hill Dam was completed during 1948 and, operated in conjunction with Dale Hollow Dam, has effected crest reductions of from 3.5 to 10 ft. in flood stages at Nashville by the retention of flood waters in these two reservoirs. This dam is a combined concrete and earth embankment structure 2,160 ft. in length with a maximum height of 240 ft. This project will control all floods of record from the 2,195 square mile drainage area of the Caney Fork River, the major tributary to the Cumberland.

Work on the powerhouse at this project is also being hurried to completion. Three 45,000 kW generators will be installed with an estimated annual energy output of 351 million kWh. Two units are scheduled to be placed in operation this autumn, and the final unit in the summer of 1951. The entire project is about 84 per cent. complete. Both the dam and powerhouse are being constructed by the Massman, Metcalf and Hamilton Construction Company of Kansas City, Missouri.

The Wolf Creek project, compared on the basis of reservoir capacity, is the largest project east of the Mississippi River. This is the key unit in the Corps of Engineers' plan for the Cumberland River Basin. The dam itself, a combined concrete and earth embankment structure, will be over a mile long. The dam will have a maximum height of 240 ft. With a

Fig. 4. Wolf Creek Powerhouse; view of the six 20-foot diameter penstocks and draft tubes; each turbine will give an output of 62,500 h.p. at 160-foot head

PROJECTS AUTHORIZED FOR CONSTRUCTION

Project	Estimated Cost	Estimate Installed Plant Capacity Kilowatts	Estimated Average Annual Energy Output Kilowatt Hours
Wolf Creek	$82,700,000	270,000	867,000,000
Center Hill	45,700,000	135,000	351,000,000
Dale Hollow	24,270,000	54,000	127,000,000
Stewarts Ferry ..	16,500,000	13,500	52,000,000
Three Islands	15,100,000	10,000	45,000,000
Rossview	9,500,000	None	None
Cheatham	15,264,000	36,000	160,000,000
Dover	16,120,000	*	*
Kuttawa (Eureka) ..	12,116,000	*	*
Old Hickory	49,120,000	100,000	420,000,000
Carthage	31,240,000	90,000	310,000,000
Celina	26,540,000	62,000	210,000,000
Subtotal ..	$344,170,000	770,000	2,542,000,000
PROJECTS INCLUDED IN THE LONG-RANGE PLANS			
Devils Jump	Not Estimated	25,000	106,000,000
Helenwood	Not Estimated	40,000	154,000,000
Rockcastle Narrows ..	Not Estimated	10,000	44,000,000
Laurel	Not Estimated	20,000	56,000,000
Subtotal ..		95,000	360,000,000
GRAND TOTAL ..	$344,170,000	865,500	2,902,000,000

*None estimated in present plans.

total of 6,098,000 acre-feet of storage capacity in the reservoir, 2,094,000 acre-feet are allotted for flood control storage. This is sufficient capacity to retain a concentrated rainfall of 7.5 in. over the entire 5,810 sq. mile drainage area, based on an average run-off of 90 per cent. which is possible during the spring and winter seasons with the ground thoroughly soaked. The dam is more than three-quarters complete and operation is scheduled for the low water season of the current year. The Jones-Wright Construction Company of Charlotte, North Carolina, is the prime contractor for the dam. Construction of the powerhouse is also being expedited; this will accommodate six 45,000 kW generators which will have an average energy output of 867 million kWh per annum.

Compared on the basis of installed plant capacity for hydro-electric projects, Wolf Creek will rank third in the eastern United States, with

Fig. 5. View of Dale Hollow Powerhouse; this is the first of the hydro-electric power plants completed by the Corps of Engineers in the Cumberland River Basin

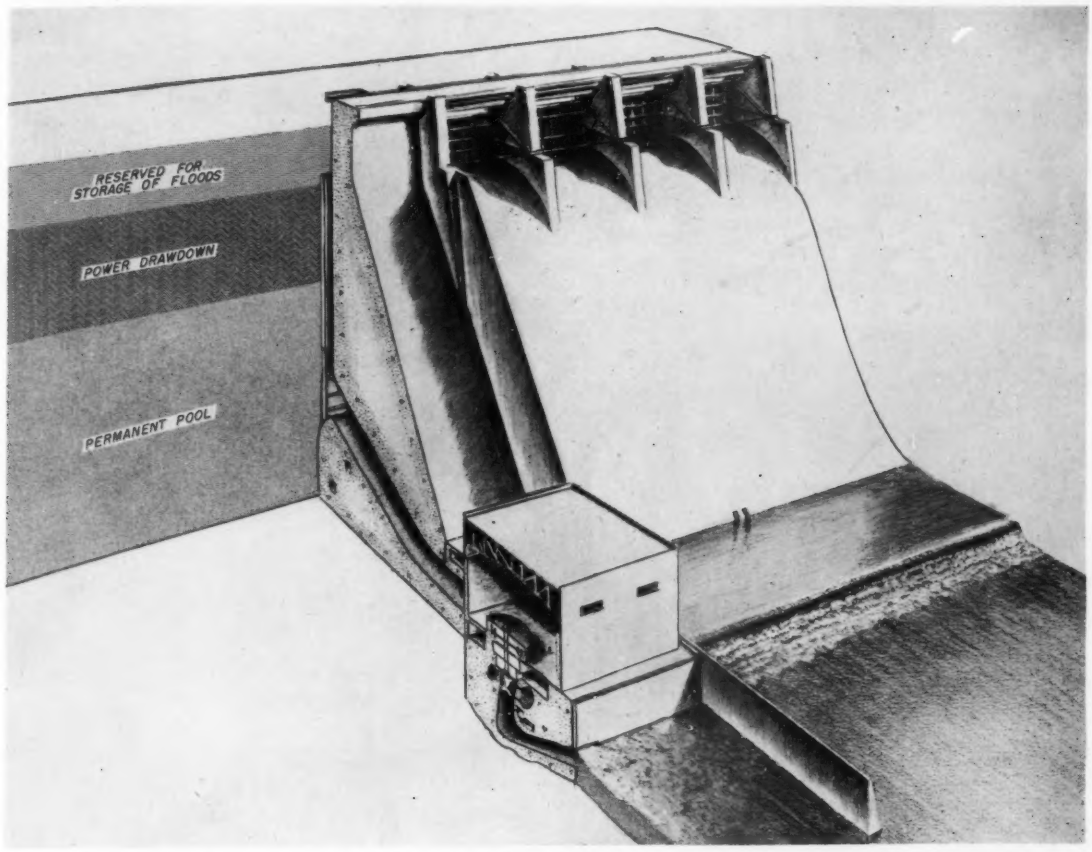


Fig. 6. Perspective drawing showing relation between reserve storage, power drawdown and permanent pool

only Wilson Dam and Clarks Hill Dam exceeding it. Wilson Dam on the Tennessee River was constructed by the Corps of Engineers after World War I. Clarks's Hill Dam is now under construction by the Engineers on the Savannah River. The schedule for power production at this project provides that three units be placed in operation in the autumn of 1951, one in the summer of 1952, one in the autumn of 1952 and one in early 1953. The A.J. Albrecht Company of Chicago, Illinois, was awarded the contract for construction of the Wolf Creek powerhouse.

Reservoir work for the Wolf Creek project presented stupendous tasks. It was necessary to relocate completely the town of Burnside, Kentucky, a place of some 900 inhabitants, with additional commercial and industrial properties. Also involved was the clearing of approximately 48,550 acres of timber and its removal from the area of inundation. Seven major highway bridges and one double-track railway bridge are being relocated prior to impoundment.

Plans and specifications for the Stewart's Ferry Dam are complete and construction work will be initiated immediately after funds for construction are appropriated by Congress. Detailed planning is also under way on the Three Islands and Rossview projects. Funds were made available during the current fiscal year to continue field investigation for detailed planning.

In the Corps of Engineers' plan of operation for multi-purpose projects certain sections or depths of the reservoir pool are set aside for specific use. As an example, the Wolf Creek Reservoir will have a storage capacity of approximately 6,000,000 acre-feet. One-third of this storage will be utilised for power, one-third for flood control and there will remain in the reservoir at least one-third, or 2,000,000 acre-feet, as a conservation pool. The flood control pool is set aside entirely to hold the spate waters until such time that the river downstream can carry them without inundating the banks.

Completion of the six reservoirs will control the run-off from approximately 66 per cent. of the 17,720 square miles of drainage area in the entire basin. This will provide the maximum practicable protection to the Cumberland Valley, and the need for local protection for Nashville by means of levees and flood walls will be eliminated. The ratio of costs to benefits for the six multi-purpose projects will be as 1.00 to 1.38. In computing the cost to benefit ratio, the costs of the projects include total construction costs amortised over a 50-year period, plus interest on investment, plus operation and maintenance costs over the entire period.

The progress that is being made by the Corps of Engineers in harnessing the flood waters of the Cumberland and its tributaries is apparent after

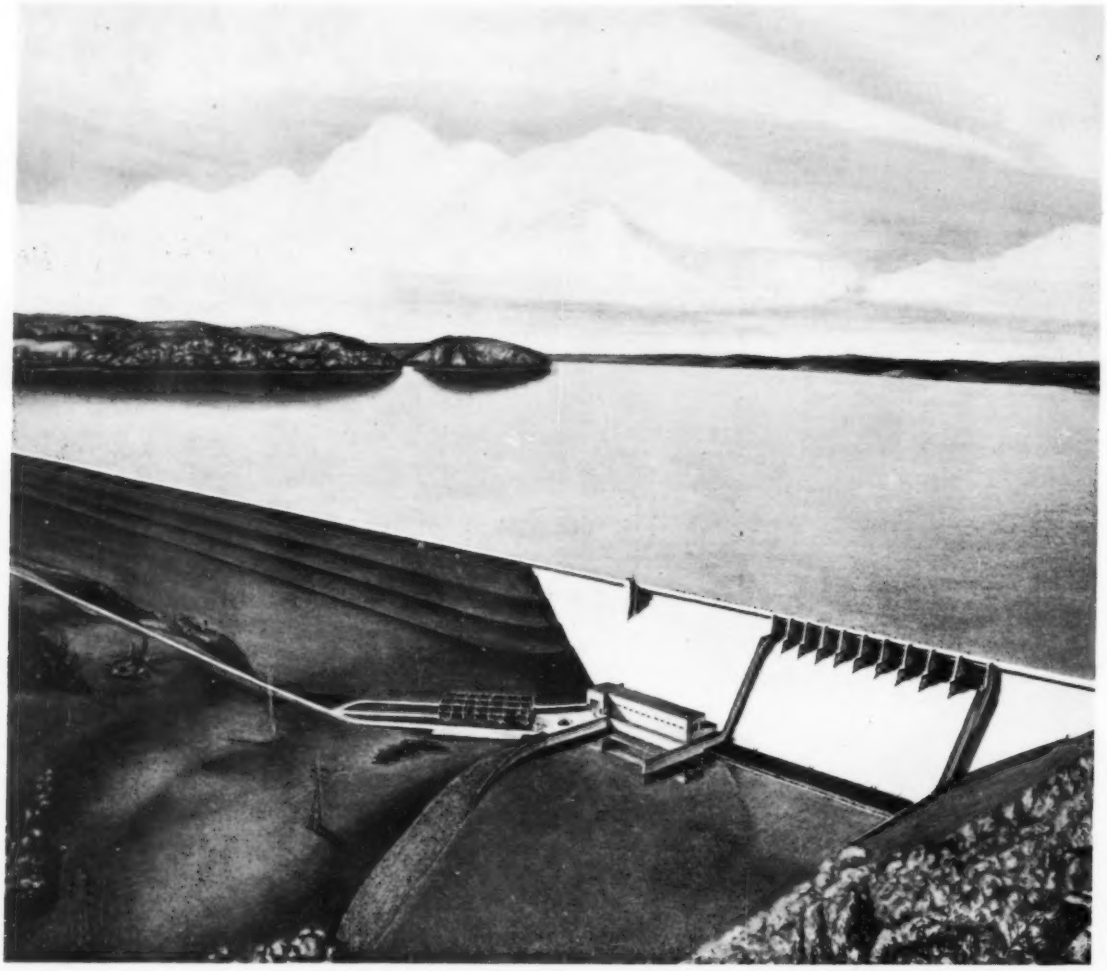


Fig. 7. Wolf Creek reservoir; artist's conception of dam and powerhouse

analysing the construction status of the various projects. Upon completion of the Wolf Creek Dam for flood control purposes, closure of which is scheduled for the low-water season of this year, its operation, together with that of the completed Dale Hollow and Center Hill projects, will control the flood waters of 76 per cent. of the basin area contemplated for ultimate control.

In accordance with recent estimates, annual flood control benefits resulting from the completion of the six-unit system will approximate $3,528,000 in the Cumberland, Ohio and Mississippi River basins. Flood control benefits from the Dale Hollow and Center Hill projects are estimated to have amounted to $848,000 during the period of 1943 through 1948 in the Cumberland River Basin alone. Additional benefits were also apparent in the Ohio and Mississippi River basins. It must also be remembered that flood control is only one feature of the programme.

The three projects in group 2 are essentially for power, but contain provisions for inclusion of locks in the event of there being an ultimate demand for navigation facilities. These three projects are located on the main stream of the Cumberland above Nashville and are designated as Old Hickory, Carthage and Celina. Heavy river traffic has never moved above Nashville in the past.

These schemes will have installed capacities of 100,000, 90,000 and 62,000 kW respectively with a total annual energy output of 940 million kWh.

In accordance with existing laws the power from all Corps of Engineer projects is turned over to the Department of Interior at the bus bar. The Department of Interior has entered into contracts with the Tennessee Valley Authority for distribution of power from the Cumberland River projects, since the TVA distribution lines are at present serving this area. In other areas, the power is distributed through existing private utility systems or Federal distribution systems.

The selected plan for projects in group 3 provides for the construction of three projects designed primarily for navigation improvement but with provisions for future power facilities. These projects were identified as the Cheatham Lock and Dam, the Dover Lock and Dam, and the Kuttawa (Eureka) Lock and Dam—all below Nashville. Initial funds for construction of the Cheatham project were included in the

Fig. 8. Wolf Creek dam; view of downstream face of 3,940 ft. embankment section

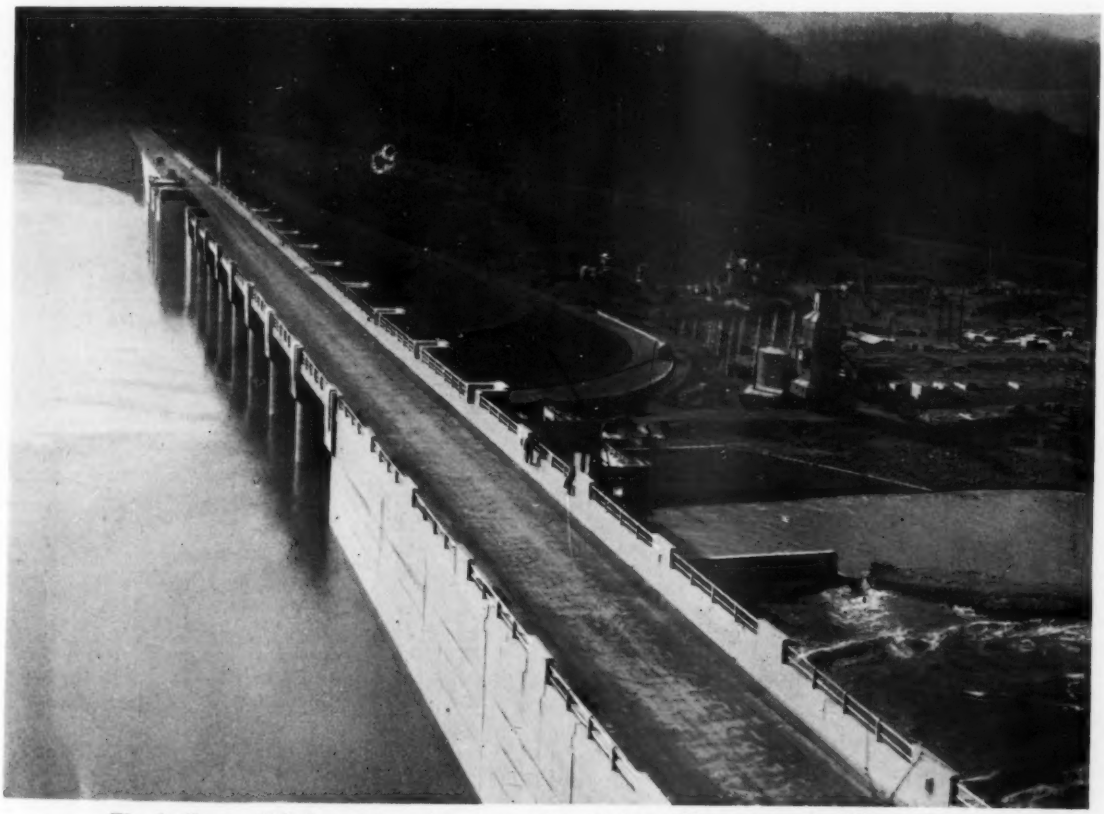


Fig. 9. Center Hill dam; view of upstream face of dam with water over spillway crest

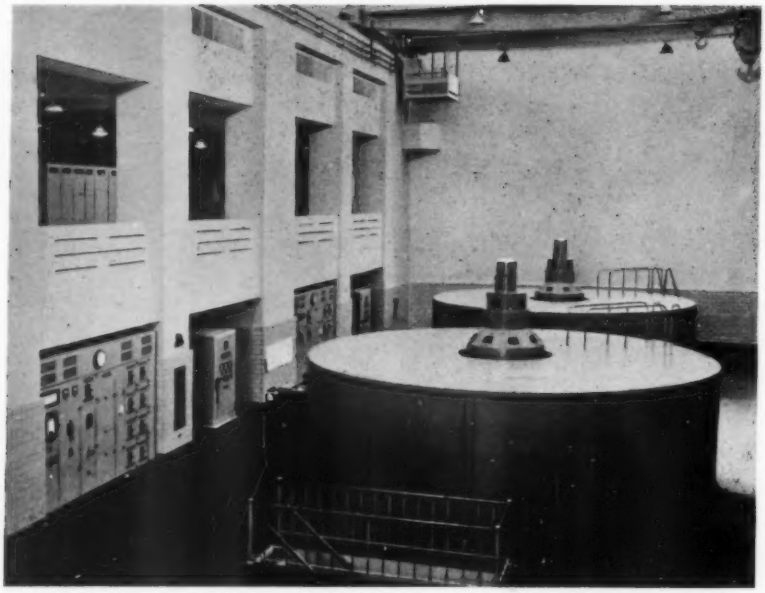


Fig. 10. Dale Hollow power house; interior view of power house showing two 18,000 kW units and field operation panels

Fig. 11. Dale Hollow project; after flood waters have crested and river downstream can take additional water without flooding its banks, the water is released through the spillway

River and Harbor Bill for the current year. A contract for construction of the lock was recently awarded to the T. L. James and Company, and Stevens Brothers and Miller Hutchinson Company of New Orleans, Louisiana. Construction work on this project will be initiated immediately. Plans for the Cheatham project have been modified to include provisions for later construction of a power plant with installed capacity of 36,000 kW.

Construction of the Dover and Kuttawa (Eureka) projects will follow in due course; reports are now being prepared for these two schemes. These three modern structures will replace seven existing small manually operated locks. The locks in the new projects will be mechanically operated and will be 110 ft. wide by 800 ft. long. This will be of sufficient size to handle in one lockage, a typical tow of nine barges and one tug. These projects will provide a nine-foot channel from Nashville to the mouth of the river and will reflect major savings in man-hours of Government operating personnel, maintenance and operating costs and a substantial saving to users. It is interesting to note that the Lower Cumberland navigation projects have one of the highest benefit-to-cost ratios of any projects presently under way in the United States.

The Cumberland River has continued to show an increasing trend in riverborne commerce, reaching a maximum of 1,384,000 tons for the year 1949. Equally

Fig. 12. Center Hill dam: this project controls the flood waters of the Caney Fork River, the major tributary to the Cumberland

Fig. 13. Burnside, Kentucky—Wolf Creek reservoir; view of area in which town is being relocated. Note water tank in foreground and water filtration and treatment plant in left background

as significant as the increase in tonnage is the increase in the amount of package freight moved over this waterway. Practically all newsprint paper used in Nashville and surrounding area is shipped over an all-water route from Labrador. Nails, wire products, steel and sugar are all items showing increased tonnages for the past year.

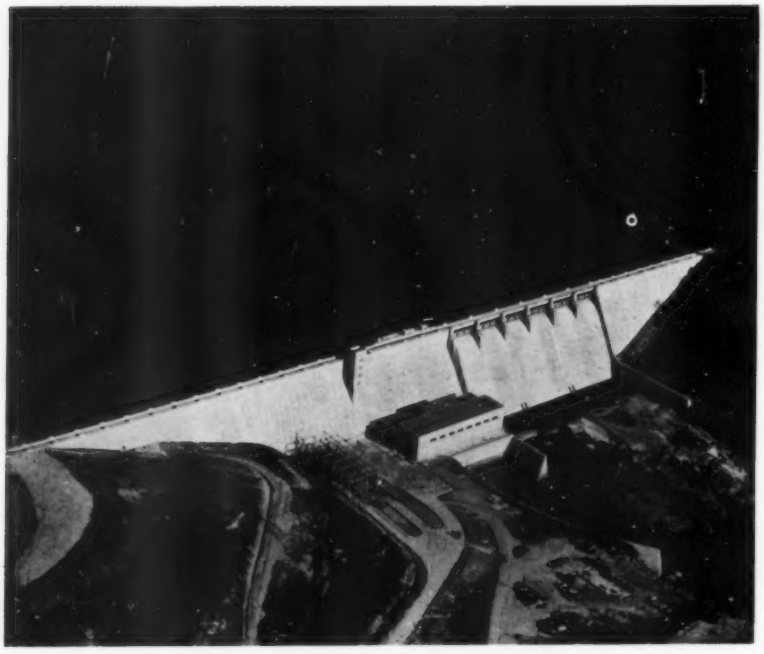
Included in group 4 and presented for future consideration are four projects on tributary streams to the Cumberland above the Wolf Creek Dam. These schemes are designed primarily for hydro-power production and will have a total installed capacity of 95,000 kW with an estimated annual energy output of 360 million kWh, but they have not yet been recommended by the Corps of Engineers for authorisation and will be deferred until the more necessary projects in the plan are completed.

The total cost of the 12-unit authorised plan, based on current estimates, is in the region of $344 million. Of this amount, $121 million, or about 35 per cent., was allocated for the fiscal year ending June 1950. Completion of the projects now under construction will represent the harnessing for useful work of 46 per cent. of the potential power capacity feasible for economic development, exclusive of the power potential in the main stem below Nashville.

For the purpose of recapitulation, the table on page 12, reflects the overall power potential of the basin, which will approximate three thousand million kilowatt hours per annum.

With the emphasis today on defence measures the power and transportation potentials of the Cumberland River have assumed special significance. A large amount of electrical energy is demanded by the atomic centre at Oak Ridge, East Tennessee, not too far removed from the headwaters of the Cumberland, and as research continues, more and more power will be needed by this American centre.

Recently, it was announced that the Government



would erect a $150 million research centre at Tullahoma, 60 miles south of Nashville, for the Air Force. Designated the Arnold Air Engineering Development Centre, this project will conduct research into supersonic and hypersonic speeds for aircraft.

This need for greater power production has led to the speculation that Congress will rush through the authorisation and appropriation of funds for early construction of all projects on the Cumberland, especially those designed primarily for power and transportation. There is already a tremendous load on existing facilities due to the influx of new industries and the modernisation of farms and local residences, many of which are now all-electric.

Fig. 14. Dale Hollow project

Harnessing the Volga

THE Russian official press has lately devoted considerable space to announcing details of its five year plan to build what is claimed will be one of the world's biggest hydro-electric power stations at Kuibyshev, on the southern Volga. A decree issued by the Council of Ministers of the U.S.S.R. gives the capacity as approximately 2 million kW and an ultimate power production of nearly 10,000 million kWh. Among the major benefits claimed for the project is that it will ensure the supply of power for industry not only in Kuibyshev itself, but in Moscow and Saratov. Plans are in hand for the electrification of railways, the irrigation of large areas around the river and the improvement of shipping facilities. The decree lays down that construction shall begin before the beginning of the present year and that the station shall be commissioned to full capacity during 1955. Other sections of the decree are listed as follows:—

Irrigation of a million hectares of the Volga area shall be provided on the basis of using the power of the Kuibyshev hydro-electric power station.

In building the station provision shall be made for placing an additional railway bridge over the Volga.

Power distribution from the new station shall be: For Moscow 6,100 million kWh annually; for the Kuibyshev and Saratov areas 2,400 million kWh annually; and for irrigation of the Volga areas 1,500 million kWh annually.

A building organisation, " Kuibyshev-Hydrostroi " is to be created to carry out construction of the power station in Kuibyshev with L. V. Komvin as head of the organisation and N. F. Shaposhnikov as chief engineer. S. Y. Zhuk is to be entrusted with the draft research work connected with this large scheme. The estimated power output of the new station is bigger than that of the Boulder Dam of the United States, and ranks in magnitude with the famous Dnieper Dam.

(Continued from page 7)

In a note on electrical equipment and heavy machinery supplies the report points out the importance of the Pakistan market for all types. " Competition from most manufacturing countries is keen," it warns, " and the energetic entry of Japanese makers of electrical and engineering plant at most competitive prices and delivery is very noticeable. Several important contracts for generating sets and other steam and electrical equipment have already been placed with Japanese manufacturers.

" In our opinion the development of the country does not yet warrant the establishment of works for the manufacture of heavy machinery and electrical equipment. There are, however, good prospects for the manufacture of light products and supplies, for which a growing demand is likely, and there are already a number of small assembly or manufacturing plants operating. British makers of such products would be well advised to consider forthwith establishing small plants in Pakistan which can be expanded to cope with the growth in demand."

The mission, appointed by the President of the Board of Trade (Mr. Harold Wilson) was led by Lord Burghley. Mr. E. C. Holroyde was the member for the electrical industry, Dr. G. I. Higson for the chemical industry and Mr. W. J. H. Rennie for civil engineering. Mr. M. J. Watt, of the Federation of British Industries, was attached to the mission in an advisory capacity.

The Study of Wave Motion

To meet the requirements of engineers engaged in building coastal structures a knowledge of wave amplitude is necessary, and in this article, which is based on a report made by L. Vantroys, Chief of the Study Services for the Utilisation of Tides for Electricité de France, reference is made to the results obtained with an interesting instrument of British origin.

WHENEVER there is a question of building an important constructional work in contact with the sea one of the first things to know about the site is the nature and the magnitude of the wave motion which the new construction must resist. Formerly, visual observation was the only means available and consisted of ascertaining the rise and fall on a fixed vertical scale erected against some convenient rock or mounted on an artificial base resting on the sea floor; further information could also be obtained by observing the movements of the water in relation to a floating beacon stabilised by a large horizontal fin. More recently, with the aid of photographs taken in synchronism, it has been possible to make a detailed examination of the characteristics of the free surface of a surging sea.

None of these methods, however, can be used during a heavy storm—precisely the time when observations would give the most valuable information.

In consequence, much is to be gained by having an apparatus placed on the bed of the sea and sending impulses that are commensurate with the magnitude of the wave motion, to some recording instrument situated in security on the shore.

Meteorologists make careful observations of wave motion along the coast as being an element which assists in the prediction of bad weather. For this purpose, they make use of manometric recordings of pressure variations on the bottom of the sea, subsequently examining them with the aid of frequency analysers. By these means a complex wave form can be analysed with sufficient accuracy to identify the portion of the ocean basin in which the storm has its origin.

An engineer who is faced with the task of building constructional works next to the sea will scarcely

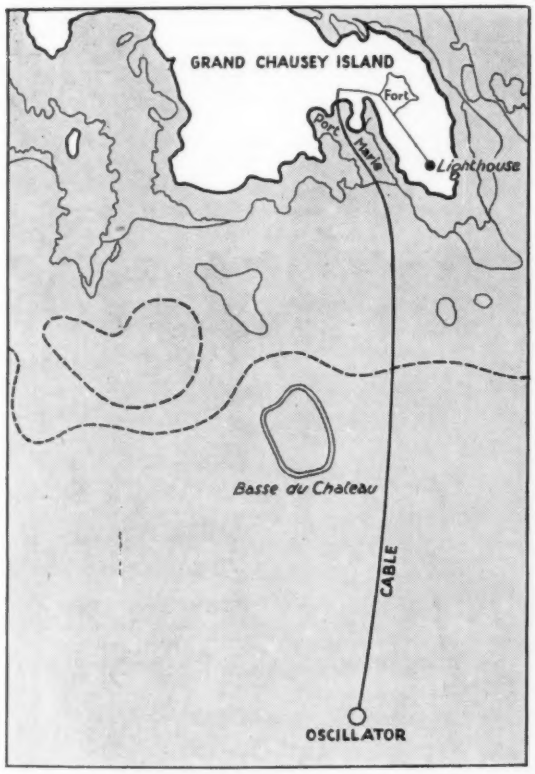
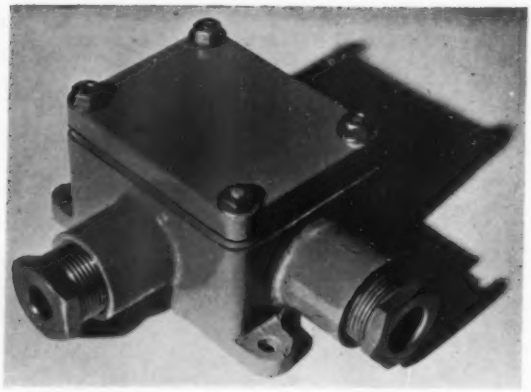


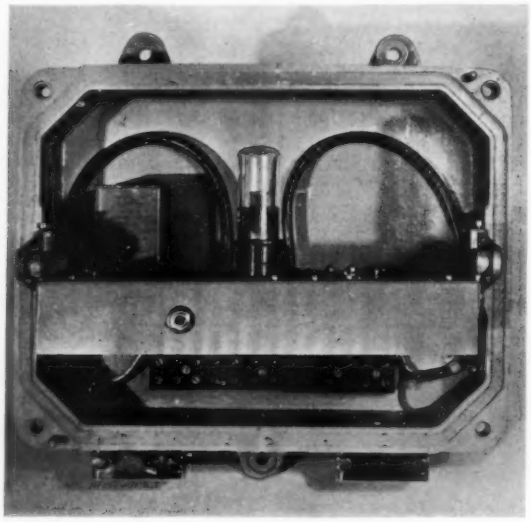
Fig. 1. Diagram showing arrangement of the wave studying layout at Chausey

Fig. 2. Transducer mounted in reflector with diaphragm removed



in Cornwall and by the French Navy, the latter using it to make recordings of wave motion off the coast of Casablanca, for which purpose it was fixed not on the sea floor but on part of the hull of a submarine. The particular application to which we would refer in this article, however, has been put into use by Electricité de France with a view to making a trial study for an installation to the south of the Chausey Isles. The apparatus has been furnished by Kelvin & Hughes (Marine) Ltd. It was immersed in May 1949 at about one nautical mile to the south

Fig. 3 (left). Junction box for landline
Fig. 4 (left, below). Transmitter power unit
Fig. 5 (below). Transmitter with cover removed



be content with an apparatus which merely records variations of pressure at various points on the sea floor, as such variations diminish in direct proportion to the depth, and also because the conversion of the readings obtained into the actual heights of the waves at the surface necessitates complicated analytical examination involving coefficients that have not been perfectly determined. An apparatus that will give a direct recording of the variation of the depth of the water is thus to be preferred.

Such an apparatus has now been constructed; it consists essentially of a "vertical sound emitter" which is placed on the sea floor, and which emits ultra-audible sounds that are reflected to the surface of the water and return as an echo, to act on the apparatus, which then functions as a receiver. It is thus possible to obtain a recording which is directly proportional to the depth of the water. An appliance of this kind has been used by the British Admiralty

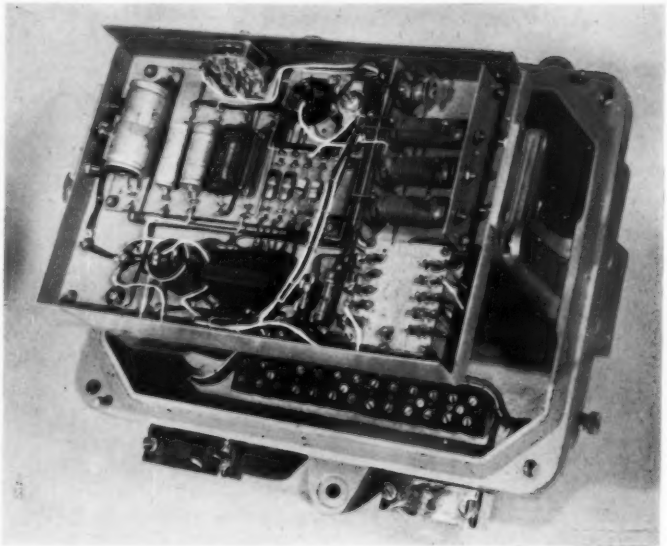
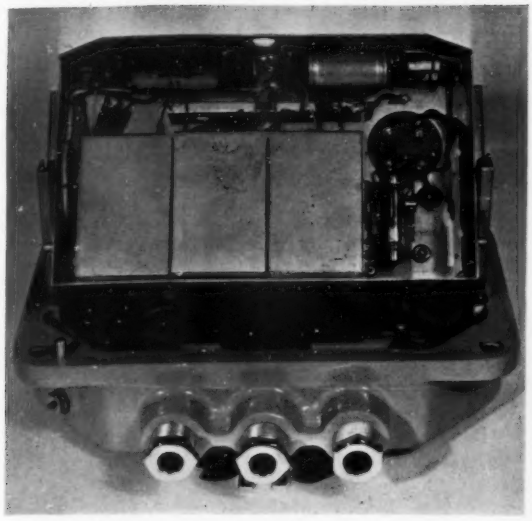


Fig. 6. Transmitter ready for servicing



of Grand ile de Chausey (Fig. 1).

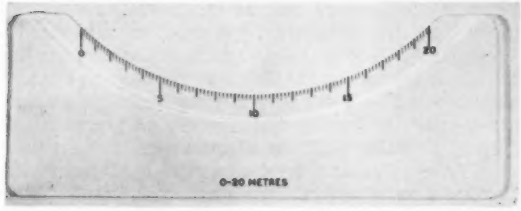
It consists essentially of an oscillation unit, a submarine cable, a transmitter power unit and recording instrument. The oscillator unit, which is shown in Fig. 2, and is located on the sea bed, consists of a magneto-striction transducer having a large reflector with a stainless-steel diaphragm as a cover. There is a junction box at the sea end of the submarine cable, to form a connection with the transducer element winding, and on completion of this joint the junction box is filled with compound to prevent breakdown of the insulation. The oscillator unit should be sited on a substantial base already

Fig. 7 (above). Amplifier with cover removed

Fig. 8 (right). Recorder and amplifier unit at Chausey

Fig. 9 (below). Scale of recording instrument — 0 to 20 metres

Fig. 10 (below, right). The converter unit

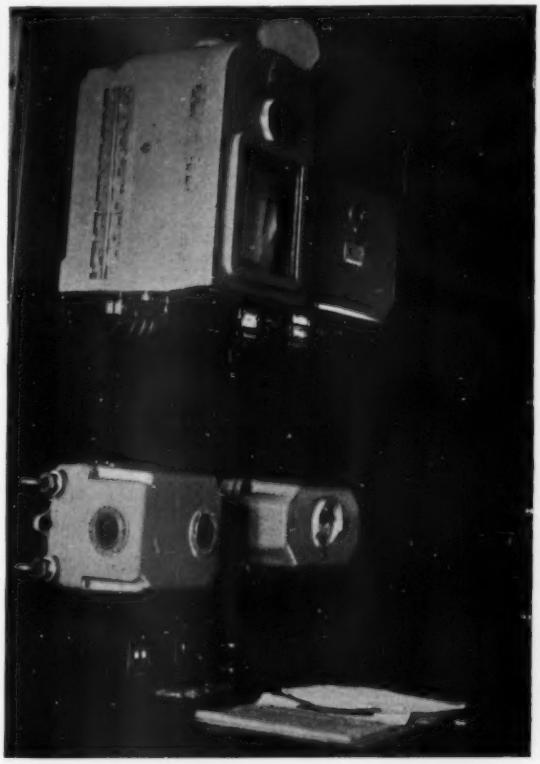


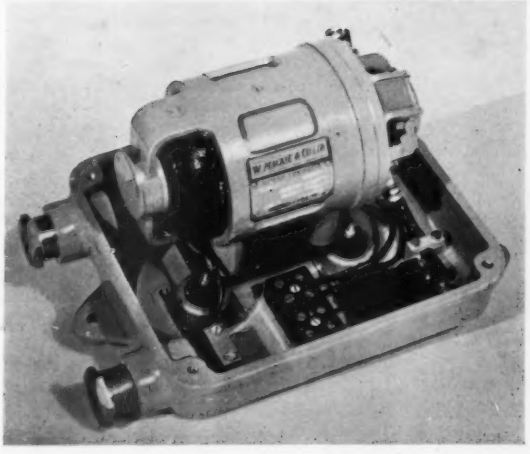
positioned so that it can be secured in such a way that the axis through the apex of the diaphragm is vertical.

The submarine cable has twin-core 7/·029 copper conductors insulated with telecothene, and is armoured with 12 × ·192 in. tarred galvanised steel wires. An outside wrapping of compounded jute yarn is provided, making an overall diameter 1·3 in.

At the shore end there is a second junction box which can be mounted at any convenient position above high-water level. This junction box connects the submarine cable to a landline which can be run above ground, on posts, to the recording station.

At the recording station a third junction box, Fig. 3, is used to connect the landline to the transmitter power unit, Fig. 4, which supplies the supersonic pulses to the transducer via the submarine cable. The energy stored in a 4-microfad condenser is discharged through a gas discharge tube into the cable and transducer, the discharge tube being triggered by a pair of contacts in the recorder. Figs. 5 and 6 show the unit opened ready for servicing. The amplifier, Fig. 7, receives the "echoed" pulse from the transducer, and amplifies it, the output from the amplifier then being rectified.





A view of the recorder is given in Fig. 8. This initiates the triggering of the transmitter power unit and records the interval between the transmission and the receiving of the rectified signal from the amplifier, i.e., the echo. The time interval is a measure of the distance that the supersonic sound pulse has travelled through the water and can thus be measured by a scale graduated in metres (Fig. 9). The width of this chart is 12.5 cm. and in this width is represented 20 metres of water. The ratio of height of water to chart width is maintained by a mechanical arrangement, and the range of the equipment can be adjusted to anything up to 80 metres depth of water in increments of 5 metres.

which varies slowly, remained from May to December 1949 within limits which did not compromise the results obtained with the apparatus. After the latter date the oscillating circuit became unbalanced as the frequency of the wave train emitted did not preserve the value of 30 kc. per sec. However, by modifying the regulation of the receiver amplifier it has been possible to obtain perfectly legible and accurate results.

The installation at Chausey has functioned in a very satisfactory manner and it seems possible that an installation of this type could function for many years. The principal disadvantage is the high cost of the armoured submarine cable, which in the particu-

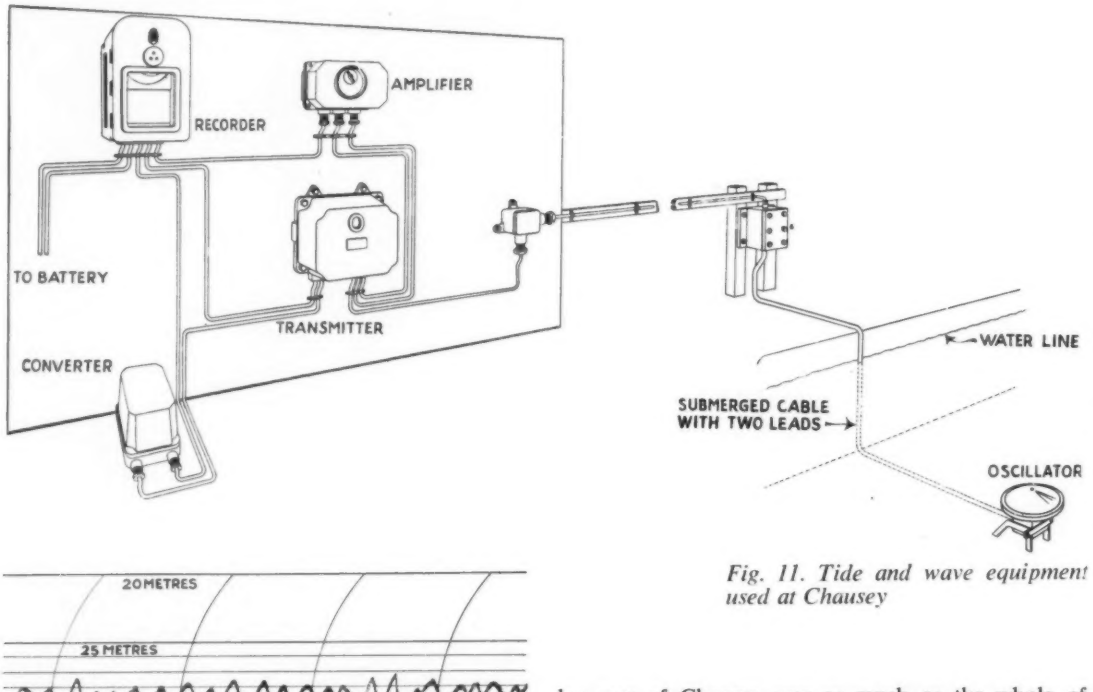


Fig. 11. Tide and wave equipment used at Chausey

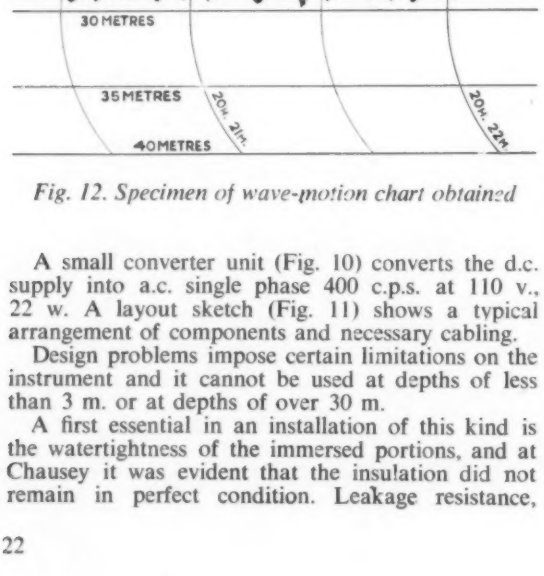


Fig. 12. Specimen of wave-motion chart obtained

A small converter unit (Fig. 10) converts the d.c. supply into a.c. single phase 400 c.p.s. at 110 v., 22 w. A layout sketch (Fig. 11) shows a typical arrangement of components and necessary cabling.

Design problems impose certain limitations on the instrument and it cannot be used at depths of less than 3 m. or at depths of over 30 m.

A first essential in an installation of this kind is the watertightness of the immersed portions, and at Chausey it was evident that the insulation did not remain in perfect condition. Leakage resistance,

lar case of Chausey was as much as the whole of the rest of the installation put together, and this for a length of 2 km. only. In conditions where the coast has a very gentle slope greater lengths of cable would be necessary and for temporary installations the cost would be heavy. In a region where it was desired to take multiple observations it mught be possible to use one vertical sound emitter to standardise a number of manametrically independent recorders that could be anchored in various points of the region to be explored.

In order to know certain characteristics of a wave, such for example, as the direction of propagation, the form of the free surface, and the division of pressures in depth, some apparatus other than the vertical sound emitter may be necessary, such as photogrammetric or manometrical recorders. But at present the vertical sound emitter seems to afford the best and the surest means of obtaining a precise recording, over an extended period of time, of the depth and the periodicity of wave motion, and from this information the effects exerted on any structures can be calculated with a satisfactory degree of accuracy.

Tungsten-Carbide Drilling Bits

A series of interesting tests were conducted on tungsten-carbide bits at Delnite Mines Limited, Ontario, by Messrs. J. H. Fulton, A. G. Douglas and J. Beattie. An account of these tests was published in the Canadian Mining and Metallurgical Bulletin* and we give a summary of the results.

THE tests indicated that to drill medium and hard ground time was saved in having fewer bits to change and fewer broken or stuck bits to remove from the hole. Time and effort were also saved in having fewer drill rods to handle.

The bit cost per foot drilled for one type of carbide bit was almost four times that for the steel bit. This comparison, it was stated, is not too accurate, as most of the carbide bits were used in the medium or hard ground whereas the steel bits drilled, in addition, considerable lengths of soft ground. In development headings the use of carbide bits appeared feasible only in the harder ground and only with a one-man-operated airleg. In stoping the work must be planned so that the number of holes drilled per shift is about doubled as compared with drilling with steel bits.

A controlled test was conducted in a drive heading using the airleg combination with another type of carbide drill rods. Rods with broken collars can be used again either by re-forging collars or using them in a tappet-type drill.

Disadvantages of Carbide Bits

The special methods and precautions that are required for the use and control of carbide bits arise from the fact that they represent the substitution of a 10 cent piece of equipment by one costing $13 to $17, depending on the type of carbide bit or drill rod used.

(1) Rigid control of bits and drill rods is essential. Each miner must be made responsible for his bits. In the case of the detachable bit this is a matter that can be taken care of in a manner similar to the present method of handling steel bits. For the drill rods with carbide inserts, however, the handling procedure is more troublesome, as it appears essential that each runner must bring out all his drill rods from the working place at the end of each shift in order to prevent loss due to blasting and possible misuse of the rods by trackmen, mucking machine crews and miscellaneous personnel.

The problem is most serious in stopes and rises where the present tendency is for the men to throw the used steel down the manways, etc. With the carbide drill rods it will be necessary for the stopemen to carry their steel up and down the manways each shift, whether it has been used or not.

(2) All new runners must be thoroughly trained in the proper use and care of the carbide bits or carbide drill rods to ensure that they are properly used. This will require close supervision for a period of time.

(3) With detachable bits the grinding problem is normal; with carbide drill rods two methods of reconditioning are possible:

(a) All rods can be brought to a centrally-located grinder;

(b) The grinder man, equipped with a portable grinder, can go to the station on each level where drilling is being done and recondition the bits.

Advantages of Carbide Bits

(1) There is an appreciable increase in tons broken or feet advanced per man-shift, due chiefly to:—

(a) The marked increase in drilling speed in medium and hard ground, amounting to 25 to 100 per cent., depending on the ground.

(b) Fewer bit changes required, a carbide bit drilling goes 7 to 10 times as far as a steel bit before it needs grinding.

(c) Enables the use of lighter drilling equipment which allows the runner to do more work with less physical effort — i.e. less rigging time is required for setting up and tearing down, giving more time for actual drilling.

(d) The psychological effect on the miner in using light fast-drilling equipment is especially noticeable in hard ground where steel bits will drill only a few inches at a speed of 3 to 4 in. per minute and runners become discouraged and dissatisfied and often do not put forth their best effort.

(2) A reduction in capital outlay for drill machines, parts, drill rods, etc.—i.e. fewer and cheaper machines for the same production.

(3) A 25 to 50 per cent. reduction in air consumption which is of importance in conditions where the air compression plant is working close up to capacity.

(4) More concentrated supervision is possible, since fewer men will be required to produce the same tonnage, thus allowing the supervisory staff to give more attention to the operations under their control.

* May issue 1950.

An Agreement has been entered into between the Eire Electricity Board and the Minister of Finance in Northern Ireland to enable the work on the partial development of the River Erne for electrical power to go forward. Total capacity of the scheme when developed will be 230 million units per annum, and the cost will be approximately £6,346,000.

Protective Hats. Stradford Products Limited have produced a light weight "hard hat," meeting all the requirements of the latest British Standard Specification and constructed from Rigid P.V.C. It can be supplied in either black, white, red or brown and is remarkably inert chemically and is absolutely impervious to moisture. It is claimed that the helmet portion is virtually indestructible and that the harness is replaceable at a very modest cost.

Notable Water Tunnel

By C. F. GRUNDY, M.Eng., M.I.C.E. Particulars are given of the Bowland Forest Tunnel which is part of the aqueduct connecting Haweswater, in the Lake District, to Manchester. Although this tunnel has been driven for domestic water supply it constitutes a constructional feat which is necessarily of interest to hydro-electric engineers.

L'article çi-dessous donne les caractéristiques d'un tunnel qui constitue l'un des éléments de l'aqueduc qui amènera l'eau du lac de Westmorland aux districts industriels de la banlieue de Manchester. Ce tunnel a 16 kilométres de long, et bien qu'il ait été construit pour la conduite de l'eau à des usages domestiques et industriels, les difficultés pratiques rencontrées, le matériel employé et la technique adoptée doivent intéresser l'ingénieur hydro-électricien. Il traverse des couches trés difficiles à percer et le ruissellement important d'eau d'infiltration a constitué un sérieux obstacle.

Se facilitan detalles de un túnel que ha sido construído como parte de un acueducto para abastecer agua procedente de un lago en Westmorland a los distritos industriales de los alrededores de Manchester. El túnel es de una longitud de 16 km. y si bien ha sido construído para la conducción de agua para fines domésticos e industriales, las dificultades prácticas experimentadas, los equipos empleados y la técnica adoptada son necesariamente de interés para los ingenieros hidroeléctricos. Tuvieron que atravesarse capas geológicas muy difíciles y los progresos fueron dificultados por la existencia de copiosas corrientes de agua.

THIS tunnel, ten miles long, forms the middle section of the aqueduct conveying water from Haweswater, in the Lake District, to Manchester, a distance of 67 miles.

From the northern portal, situated about 12 miles east of Lancaster, Fig. 2, the line of the tunnel is practically due south under the Bowland Hills to the valley of the Hodder river about eight miles north of Clitheroe. On the borders of Lancashire and Yorkshire, the country is open moorland with few roads and is difficult of access. The nearest towns are Lancaster and Preston.

The rock strata encountered in the tunnel driving are sedimentary of the Carboniferous series, chiefly shales and gritstones in the northern section, changing to limestone at the southern portal. There are

Fig. 1. View of one of the power stations supplying electric power and compressed air for tunnel driving. On the right can be seen the waste-heat boilers

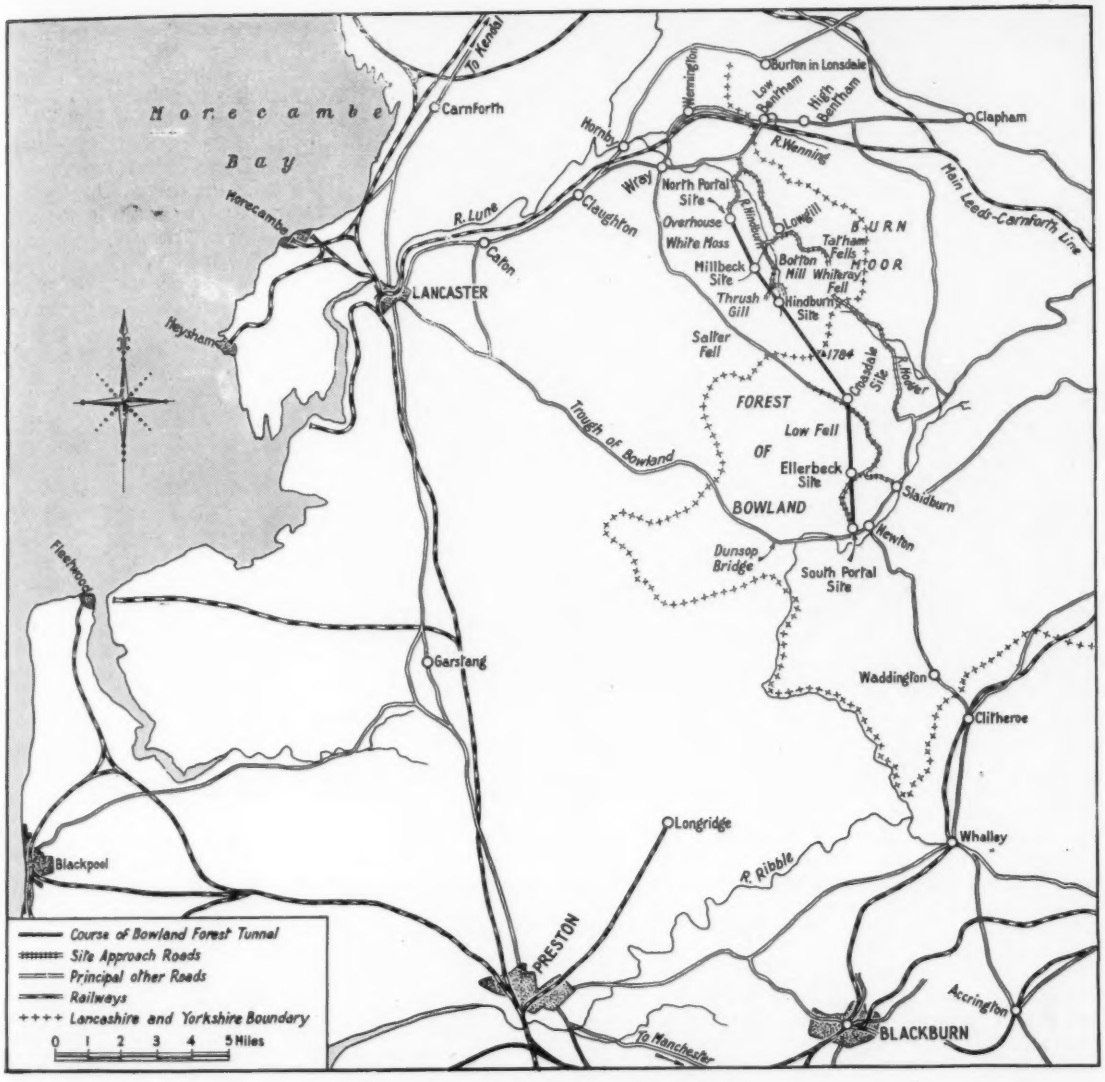


Fig. 2. Map showing location of Bowland Forest tunnel

numerous faults and probably few tunnels have been driven where the conditions encountered in driving are so liable to change from round to round.

Two major hazards have to be considered—unstable rock conditions requiring temporary support, and water. For the 11 ft. × 11 ft. horseshoe section of the tunnel, temporary support by steel arches and steel lagging or " bank bars " has been found to be the most suitable for coping with the varying conditions encountered from day to day in the different headings.

The standard support is shown in Fig. 3 and consists of 5 in. × 4 in. steel arches at 4 ft. centres with steel angle struts and $\frac{3}{8}$ in. bank bars. When required, the spacing of the arches is reduced to 3 ft. or even 2 ft. where the ground pressures are high. This type of support is rarely badly damaged by blasting even when conditions require it to be placed up to the face, while there is no difficulty in replacing one or more arches if this should be necessary.

Certain sections of the tunnel have been driven in a soft mudstone which, under the action of air and the little water seeping through the beds, turned into a soft clay requiring " spiling " ahead of the tunnel face; while in the floor hard shale requiring blasting may occur in conjunction with this soft material. Here again, the steel arches with " bank bars " have been used instead of the customary timber frames and spiling boards, and steady progress of 20 to 25 ft. per day has been made in these conditions.

For the side walls *in situ* concrete support is provided as soon as possible after driving, to prevent further disintegration of the mudstone and, for the same reason, a concrete sub-floor is laid where required, both operations being carried out while the driving is in progress.

In the driving of the southern portal heading, unexpectedly difficult ground has been met. For the first

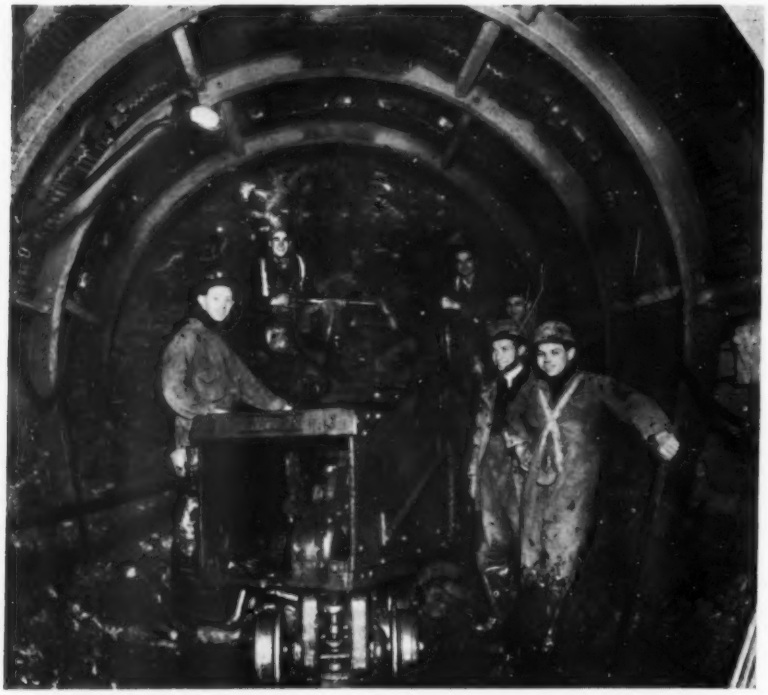


Fig. 3. Bowland Forest tunnel heading in shale and gritstone strata showing the use of steel arches for temporary support

hundred feet a good solid massive limestone seemed to indicate ideal tunnelling ground ahead but this changed to what can best be described as random blocks of limestone in a clay matrix. Steel arches and bank bars right up to the face are insufficient to hold the ground and "spiling" is not possible due to the limestone. In these conditions forward support is provided by drilling 3 in. diameter holes, in the roof ahead of the tunnel face, in which rails are driven from over the top of the arches. These hold up the roof of the heading until enough ground can be excavated for an arch to be placed. A round of 3 ft. is all that can be attempted in this type of ground and progress is dependent on the conditions, varying from 6 to 20 ft. per day.

Where shale and gritstone beds are encountered, lying more or less horizontally, temporary support is still often required, but here the steel arches are replaced by a hanging form of support. Holes are drilled, from 4 to 6 ft. deep, more or less vertically into the roof into which 1 in. diameter bolts having an expanding nut are inserted; by turning the head of the bolt, the nut, which is a tight fit in the hole, is expanded and the bolt is thus anchored to the upper strata above the roof of the tunnel. Roof support is then merely a matter of a few "bank bars" and pages between the bolts. This method is very economical in the use of steel, the quantity being about one-sixth of that required with steel arches and bank bars.

As the gradient is only 1 in 3,000 any water encountered in tunnel driving requires to be pumped. At the tunnel face, under normal conditions where feeders up to 100 g.p.m. may be encountered, the usual compressed air driven centrifugal or ejector type pump is employed.

Outby of the face and for dealing with large inflows of water, diesel-driven self-priming centrifugal pumps of a low head characteristic are universally employed, each pump delivering direct into a large diameter pumping main leading to the tunnel portal in the case of open headings or to a central sump at the shaft bottom.

Two sizes of diesel pumps are employed—a small 4 in. unit driven by a 5 h.p. engine capable of delivering up to 200 g.p.m. at 25 ft. head, and a

Fig. 4. Tunnel in mudstone showing "bank bars" used as spiling with "in situ" concrete support to walls

Fig. 5. A view of Thrushgill camp

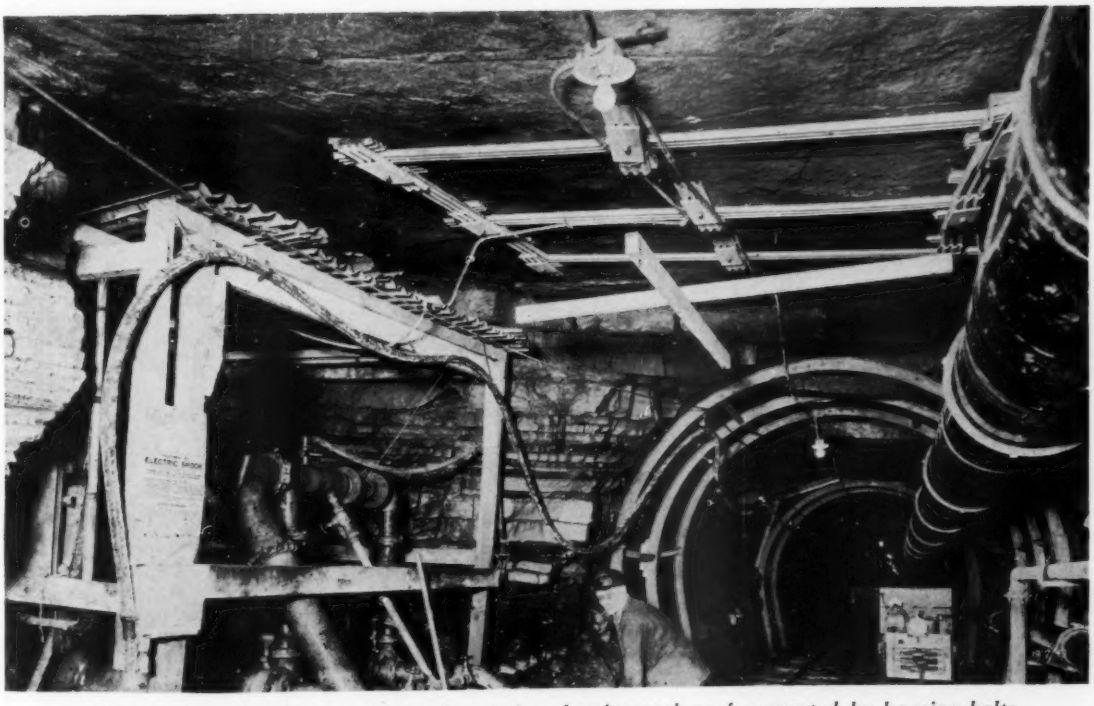


Fig. 6. View of underground pumping station showing rock roof supported by hanging bolts

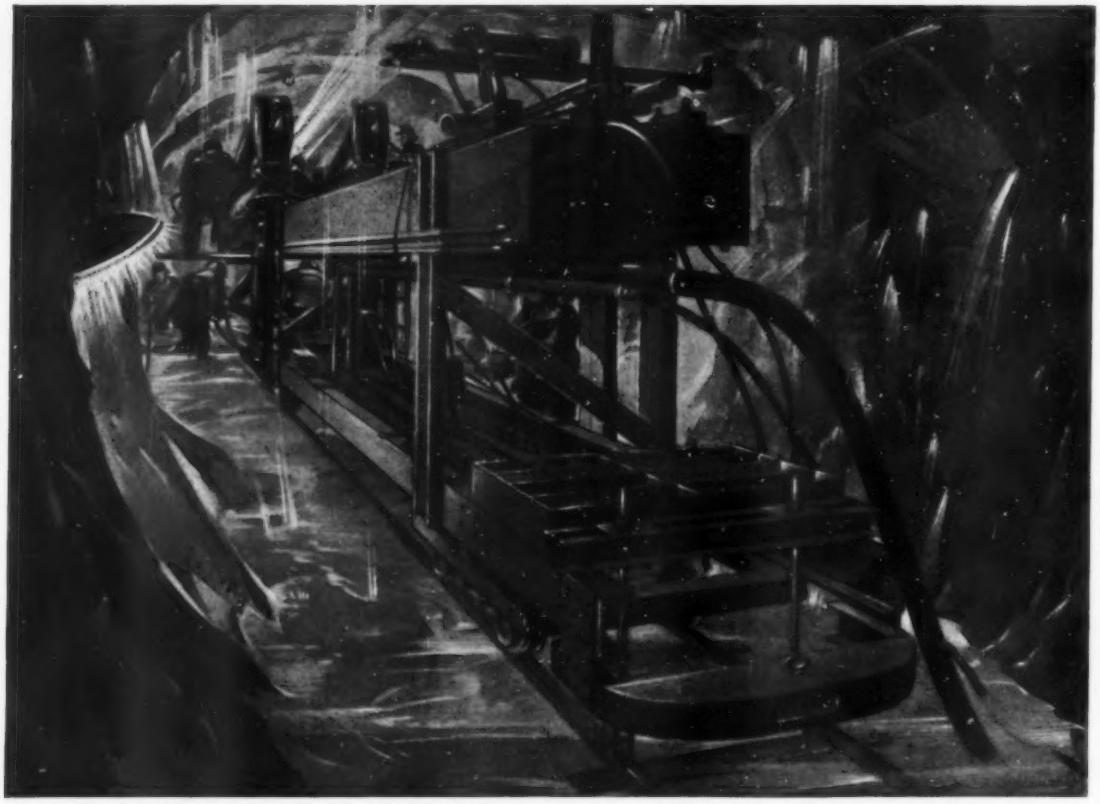


Fig. 7. Drilling a round in the Hindburn heading using heavy drifters mounted on a jumbo

Fig. 8. Typical infiltration of water in the Hindburn heading. The upper left pipe is the ventilation main; the lower pipe is the pumping main

larger 10 h.p. 6 in. unit capable of handling up to 600 g.p.m. The exhausts from the pumps, if there are any number in the tunnel, deliver into the tunnel ventilation line which is kept permanently on suction. The system is found to work well and there are no harmful effects other than a tendency for excessive

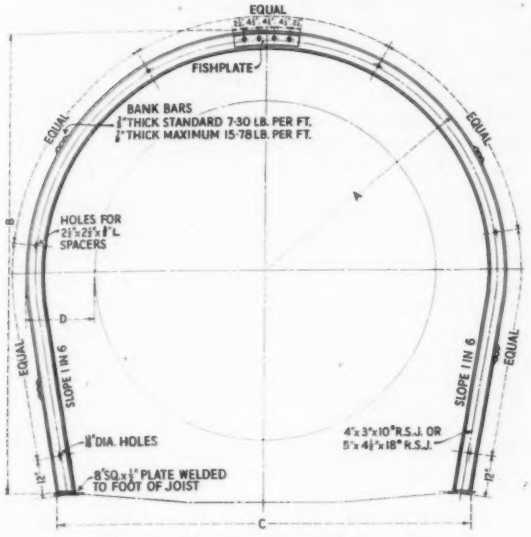


Fig. 9. Detail of arched support

driven through shales and gritstones directly under the Bowland Hills. A peculiarity has been that in the last three thousand feet of this drive the water has been met with at the face almost continuously, and sometimes at sufficient pressure and quantity to make it necessary to fire half the face at a time. Even so the total quantity handled—over 2 million gallons per day — has not varied substantially, each new feeder reducing the feeders back of the tunnel face. This heading will ultimately be 13,000 ft. long, and a 24 in. pumping main has been provided which will enable it to be driven with a total water make of 3,000 g.p.m. If water in excess of this quantity is encountered, it will probably be necessary to stop driving and line a section of the tunnel so as to seal off some of the inflow by grouting.

Tunnel driving has been in progress for slightly over two years and the fifth mile has just been completed. Generally, work is proceeding on four or five faces simultaneously with an overall progress of 90 ft. to 100 ft. per day. Individual progress on the various headings largely depends on the physical conditions being encountered, now that the crews are trained and the incidence of labour turnover is reduced. The best progress to date has been 236 ft. in seven consecutive days, in a shale and gritstone bed requiring continuous steel arch support right up to the face.

Experience has been obtained in various methods of drilling. In some headings, a drill carriage mounting five drifters on bars has been successfully used, applied under greatly varying conditions. A modifi-

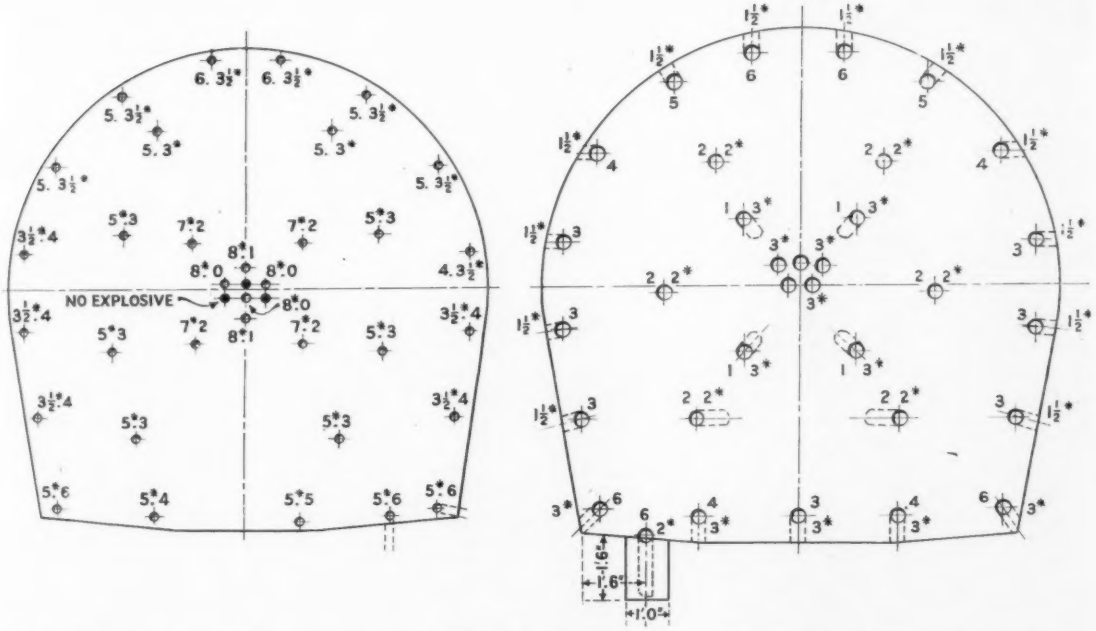


Fig. 10. a, *left;* b, *right. Diagrams showing position of shotholes and weights of charges used in different strata*

corrosion in the ventilating main due to the sulphur impurities in the fuel used in the diesel engines.

The quantity of water encountered in a heading varies tremendously. High flows, for example, have been encountered in the Hindburn heading which is

cation of the carriage with four of the drifters mounted on booms having a 6 ft. length of feed was also used for some months and gave improved performance. Maintenance of the booms, particularly the feed shells, was found to be a disadvantage which

Fig. 11. Headgear for sinking Croasdale shaft 265 ft. deep

will probably be overcome in later models. Both types of drill carriage were designed for drilling the " burn cut," the centre drifter being mounted on a short and rigid column bar at the centre of the tunnel to enable the parallel holes which are the essential feature of this type of cut to be drilled quickly and accurately.

With the drifters, 1¼ in. drill steels with detachable bits have been used, the bits being sharpened after use on a hot miller.

In other headings, a combination of light jackhammer on a leg mounting, using steels having hard metal inserts, has been used to advantage. In the type of ground encountered, the overall speed of drilling a round of 35 holes with jackhammers has been only slightly greater than when using the drill carriage and there are of course considerable economies in labour and compressed air with this method.

It has also been found that untrained personnel learn to operate the light machines more quickly than the heavier drifters. Probably under present-day conditions of employment the lighter machines are the best, but where a highly trained crew is available, capable of taking advantage of the higher speed of drilling with the heavier machines, there is no doubt as to which method is superior for speed.

The type of round and the loading of the holes has varied tremendously as can be gathered from the range of explosive consumption which has varied from 1 lb. to 7½ lb. per cu. yard—the latter in a gritstone. Fig. 10 shows *a* and *b* typical drill rounds and loading diagrams for different strata.

Mucking procedure is standardised in all headings and consists of Eimco 21 loaders filling 40 cu. ft. capacity U type cars on 2 ft. gauge track, with a " California " switch kept a short distance from the face. Haulage is by electric loco at the face with diesel locos as required to supplement.

For a period of some months an Eimco 40 loader was tried out in one heading, but it was clear that to obtain the full benefit of this machine it was necessary to use 3 ft. gauge track throughout, and the radical change of equipment required was not justified by sufficient promise of increased performance.

Tunnel services follow the usual pattern with the accent on ventilation, up to 6,000 cu. ft. of air per min. being blown or exhausted as required through a 23 in. duct, the pipes being made in a small factory established on the site. Extensive tests, carried to destruction, on experimental pipes showed that existing formulae for design of ventilation mains were on the conservative side and full advantage of the test results was taken in the final design of these mains, one of which is supplying air to a heading three miles in length.

Electric lighting is supplied at 110 v., the main supply to the tunnel coming in at 3,300 volts with transformers every 250 yards. This cable also supplies electric power for pumping at six permanent installations which handle large inflows of water.

Access to the tunnel headings is obtained from an adit and two shafts, one of which is 90 ft. and the other 265 ft. deep. The shafts are 18 ft. in diameter and are equipped with cage hoists and automatic winders. Each cage is capable of accommodating two muck wagons in tandem or a diesel or electric locomotive, with a hoisting speed of up to 150 ft. per minute.

Electric power and compressed air is supplied throughout the whole ten-mile length of the tunnel workings from two power houses, the southern installation at Ellerbeck consisting of three 267 kW diesel-electric generators and three 680 cu. ft. per min. compressors which deliver air at up to 125 lb. per sq. in. pressure. Waste heat from the exhaust gases is utilised for the central heating of the camps and for the provision of domestic hot water supplies, the power houses being located close to the camp site on this account.

The inaccessibility of the sites has required the construction of several miles of access roads and two camps for housing the six hundred workers employed on the scheme. These are built on the usual pattern with single cubicles for each man, central dining rooms, dry and wet canteens and other recreational facilities.

It is expected that tunnel driving will be completed by the winter of 1951 when the concrete lining operations will commence, and it is anticipated that the tunnel will be ready for use early in 1953. The methods used to line the tunnel will be described in a subsequent article.

The works are being carried out under the direction of Mr. Alan Atkinson, M.Eng., M.I.C.E., M.Inst.W.E., Engineer and Manager to Manchester Corporation Waterworks, Mr. L. Bendelow, M.I.C.E., A.M.I.W.E., being the Resident Engineer on the site. The contractors for the work are The Cementation Co. Ltd., of Bentley Works, Doncaster, for whom Mr. J. Widdowson is agent.

Wakefield Mechanical Grease Lubricator.—An improved type of this lubricator, the 2G, is now being marketed by C. C. Wakefield & Co. Ltd. and has been designed to handle a very much wider range of greases than the previous version which it replaces.

Loch Sloy Control Equipment

The control equipment at Loch Sloy for the four 32,000 kw generators is the first of its kind to be installed at a hydro-electric plant.

KNOWN as Miniature Direct Wire Remote Control, the system installed at Loch Sloy has been developed by Standard Telephones and Cables Limited for the complete control and indication of the station's four 32,000 kW generators and six 132 kV feeders. As will be gathered from our illustration, all the turbine, generator and switchgear controls, and meter readings necessary for the operational efficiency of the station, are centralised in one room, the equipment comprising a generator control desk and a wall-type indication and control diagram.

The desk accommodates four generator control panels, two alarm display panels and a 20-line cordless private branch telephone exchange. The finger-tip controls consist of small telephone-type keys (1 in. dia. knobs), and are so grouped that the operator sitting at the desk has full command over all four generators and can synchronise, adjust loading, or switch them without leaving his chair. All turbine, generator, and switchgear protection devices are continuously monitored by an alarm system to ensure that any abnormality is instantly indicated. The wall diagram shows in mimic the electrical arrangement of the station and the water and oil systems of the turbines, the lines and symbols being painted in suitable colours on an eau-de-nil background.

Based upon telephone technique, the system is operated by a 50 V circuit using only a few milliamps. The cables involved are no heavier than those normally used in telephone circuits and they can be grouped closely together with a great economy of space. The lightness of the cables used is a factor of some importance at Loch Sloy where the switchgear is sited about threequarters of a mile distant from the power house.

Each generator panel carries speed and voltage control keys, one generator circuit-breaker control key, and four 4 in. diameter indicating meters, *viz.*

megawatts, power factor, rotor volts, rotor amps. The alarm display panels are accommodated in the wings of the desk. The one to the left of the operator displays in groups 17 alarms for each of the four generators with a fifth group for miscellaneous alarms. The panel on the right displays in groups six alarms for each of the feeders and 13 alarms for the bus section and line protection. Each alarm lamp is wired *via* a relay to the alarm-originating contacts on the associated protective device, and on the occurrence of an alarm the lamp flashes and a common alarm bell rings. The alarm-accepting key for the group is then pressed to silence the bell and steady the lamp. A total of 168 alarms is accommodated of which 121 are at present wired to generators and feeders, the remainder being reserved for future feeders.

The wall-type indication and control diagram shows the electrical arrangements of the station and the water and oil system of the turbines. The lines and symbols are painted in suitable colours and the circuit breakers and isolators are indicated by three-colour single-aspect lamp indicators. Control keys for feeder and bus section circuit breakers are placed adjacent to their indicators.

The centre panel carries six 6 in. meters, *viz.* megawatts (TGL) megavars synchroscope, frequency, incoming volts and busbar volts. Individual feeder currents are indicated on 3 in. dial instruments set in the feeder lines on the diagram.

Additional automatic facilities at both the desk and diagram cover the automatic selection of synchronising voltages when any breaker is selected prior to closing, and a key fault alarm; with the fault alarm, if more than one breaker is selected at any one time both selections are rendered ineffective and the selection keys must be restored to normal.

Salmon and Hydro-Electric Operations

UNLESS proper precautions are taken the effect of hydro-electric schemes on salmon fisheries may be far from happy. The creation of a reservoir in the course of a river may eliminate completely some of the choicest pools, and a dam, even a very modest dam, may destroy the whole stock of salmon in a river by preventing them from reaching the only available breeding grounds.

The inundation of choice stretches is one of the inevitable and unavoidable incidents attaching to these necessary industrial developments. The second can be avoided altogether or the potential damage reduced materially by appropriate remedial measures.

Salmon and sea trout are among a relatively small band of fish which lead an odd life. The spawn is deposited in gravel in fresh water and the resulting young fish spend usually two years feeding and growing very slowly in the tributaries, lakes or main river. During that time they look like trout and are called parr; but in their second spring they become quite silvery, like adult salmon, are called smolts and move out to sea. They are about six inches long and weigh only a few ounces.

There they meet quite different conditions though where they go (possibly a long way to the west) or exactly what they eat, we do not know. Anyhow, after one year the smolt of an ounce or two may become a grilse of 3, 6, or even 8 pounds; other smolts that stay two years continually in the sea, as many of them do, weigh from 8 to 18 pounds. A more limited number stay three years in salt water and then weigh 25 to 35 pounds. The almost legendary salmon of forty, and very occasionally fifty, pounds are not old grandfather fish; they almost certainly have never been back to fresh water but have devoted four years, or possibly more, to continuous intensive feeding in salt water.

A pass for the fish may be created by forming a continuous series of pools supplied with water from the reservoir and forming a "stairway" or "ladder" with a rise of one and half or two feet between each pool. Or a fish lock can be constructed much after the fashion of, but on a much smaller scale than, a navigation lock on a river or canal. In certain siting arrangements of the power station and dam a lift may be constructed and forms a very effective means of ascent; the fish enter a trap in the tailrace and are hoisted mechanically in part of the trap containing water and then conveyed over the top of the dam into the reservoir above.

Once the adult fish are upstream of the dam the resulting young fish have to come down past it to the sea. Arrangements for their passage economically and successfully are by no means so easy as the ladder, or other device, for taking the adults upstream. So far as we know at present they cannot safely go through a turbine with a head of more than 150 ft. Grids to keep them out of tunnels and pipe lines must necessarily be of very small mesh with all the costliness and difficulties of cleaning which such screens imply.

This problem of the safe descent of the smolt is the most difficult of all those connected with salmon in relation to hydro-electric schemes but it is not insoluble, and various lines of approach have been, or are being, explored.

In Scotland as a whole the annual value of salmon fisheries is divided almost equally between nets in sea and estuary and angling in the river. About 2,000 men may be directly employed working the Scottish nets. Many ancillary interests benefit from netting and angling, such as gear and boat making, rod tackle making, ghillying and the hotel industry and so on besides the benefits to taxes on the rateable values.

Soil Test for Earth Dams

The authors describe a laboratory test procedure to obtain the effect of moulding water content and compacting, and of plotting the results graphically.

By W. J. TURNBULL* and JOHN L. McRAE†

DATA obtained in the past several years on cohesive soils have shown that the strength characteristics vary considerably with variation in moulding water content and density. The pronounced effect of moulding water was more or less expected on soils tested in the " as-compacted " condition, but quite surprising and unexpected was the finding that the moulding water content was a very material factor in the entire future behaviour of the soil, even after saturation was reached.

Laboratory tests are performed on compacted soil samples in order to establish the proper combination of water content and density at which the soil should be compacted in the field and to evaluate the strength characteristics of the compacted soil. Yet, in field work, it is very difficult to control the moulding water content and compacted density to any given specific values. Even with very careful control there are always variations in water content and density in compacted soils. Therefore, it is important that the effect of these two variables be recognised clearly.

Because of the great amount of laboratory and field experimental work being performed by the Soils Division, Waterways Experiment Station, the need for a test procedure and a method of data presentation to cover these two variables became acute as early as 1943. At the request of, and under general instructions of, the senior author, the junior author, working under the supervision of J. B. Eustis, evolved the method of test and data presentation described. There are presented herewith a procedure of testing and a method of presenting test data from laboratory compacted samples which clearly show the effect of moulding water content and density on the strength behaviour of compacted soils and which are applicable to compacted embankments and foundations.

The test procedure and method of presenting test data on compacted soils as given here were first developed in the study of the California Bearing Ratio (CBR) in connection with military airfield investigations performed by the Waterways Experiment Station.* However, the test procedure and method of data presentation also have been found to be very useful in handling unconfined compression and triaxial shear test results on compacted soils. Considerable promise also is shown in studying permeability, swell, and consolidation characteristics of compacted soils. As a result, the test procedure and method have direct application in the control of construction of all types of earthen embankments, particularly in the higher dams where rigid control of compacting moisture and density quite often is necessary in order to avoid the development of detrimental excess hydrostatic pore pressures.

The effect of moulding water content and density on the strength characteristics of compacted soils varies for different soil types and can be indicated best by the proposed presentation of laboratory tests. The data presented in this paper are not to be taken as indicative of the characteristics of any given soil type but are presented for illustrative purposes only.

Schedule of tests. In order to obtain a complete picture of variations in the physical behaviour of compacted soils with variations in moulding water content and density based on laboratory tests, the procedure followed is as given below:

(a) A practical working range of water content and density to be expected in the field must first be assumed.

(b) Compaction curves for three different compactive efforts are developed. The efforts used should cover the assumed field working range of density and water content. Laboratory tests, such as triaxial shear or unconfined compression tests, are performed on each specimen used in the development of the compaction curves, so that the variation of the physical behaviour of the compacted soil within this range can be established. The tests may be performed on samples for the " as-moulded " condition or the samples may be saturated.

Presentation of data. From data obtained by the above procedure, a family of curves is developed. Fig. 1 shows such a family for triaxial shear data. The triaxial shear tests were performed on specimens for the " as-moulded " soil condition. The graph at the lower left shows a plot of moulding water content versus dry density for the three dynamic compactive efforts used. The graph immediately above shows a plot of moulding water content versus deviator stress for each of the specimens used in the development of the three compaction curves. The graph in the centre shows a plot of density versus deviator stress for various constant moulding water contents. This plot was obtained from the corresponding left-hand plot by taking, at a constant moulding water content, the moulded dry densities and the corresponding deviator stress values for each value of dry density.

*"Compaction and Strength Tests on Soils," by W. J. Turnbull, paper delivered at the annual meeting of the American Society of Civil Engineers in New York in January 1950, and published in the *Engineering News-Record*.

*Waterways Experiment Station Report, T.M. 213-1, The California Bearing Ratio Test as Related to the Design of Flexible Pavements for Airports, 1 July 1945.

†Engineer, Soils Division, Waterways Experiment Station, Vicksburg, Miss.

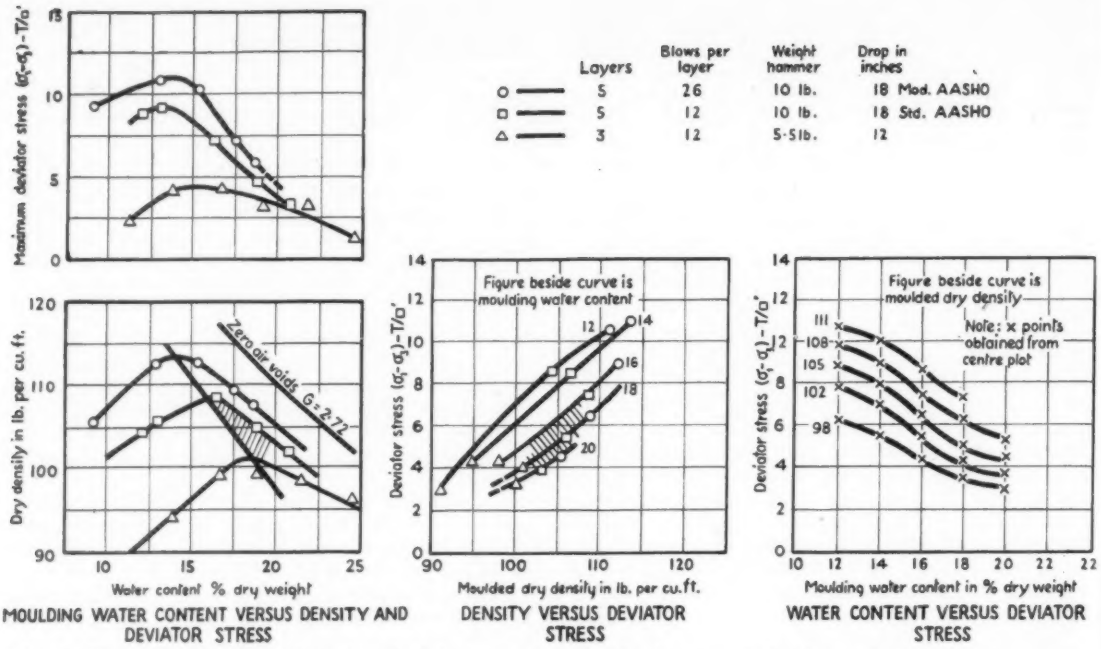

Layers
Blows per layer
Weight hammer
Drop in inches
5 26 10 lb. 18 Mod. AASHO
5 12 10 lb. 18 Std. AASHO
3 12 5-5lb. 12
Maximum deviator stress (σ1-σ3)-T/σ'
Dry density in lb. per cu. ft.
Zero air voids G=2.72
Water content % dry weight
MOULDING WATER CONTENT VERSUS DENSITY AND DEVIATOR STRESS
Figure beside curve is moulding water content
Deviator stress (σ1-σ3)-T/σ'
Moulded dry density in lb. per cu.ft.
DENSITY VERSUS DEVIATOR STRESS
Figure beside curve is moulded dry density
Note: x points obtained from centre plot
Moulding water content in % dry weight
WATER CONTENT VERSUS DEVIATOR STRESS

Fig. 1. Chart showing variations in triaxial shear values with changes of density and moisture; tests were conducted on specimens in the "as moulded" condition

Each pair of these values gives a point on one of the curves shown in the centre plot.

The graph on the right of Fig. 1 shows a plot of moulding water content versus deviator stress for various constant moulded dry densities. This plot was obtained from the centre plot by taking, at a constant moulded dry density, the corresponding deviator stress value for the different values of moulding water content. Each pair of these values gives a point on one of the curves shown on the right-hand graph.

Variations are readily demonstrated of the effect on the soil strength of different testing procedures such as consolidated undrained, unconsolidated undrained, and consolidated drained triaxial tests. Also, the variation in strength effects of taking yield, maximum, or ultimate values can be shown.

The development of the complete strength picture of a soil requires somewhat more work in testing, but it is believed that this can be offset easily by the careful selection and testing of fewer and more representative samples of soil. The procedure for obtaining the family of curves for unconfined compression, permeability, CBR, or other tests on compacted soils is the same as that described above for triaxial shear. Triaxial shear was chosen merely to illustrate the method.

Application of the curves. Plots of test data, as in Fig. 1, separate the two variables that have the greatest effect on the strength characteristics of compacted soils—moulding water content and moulded density. This permits an evaluation of the effect of moulding water content and compacted density on the strength of a soil and shows whether or not it is necessary to maintain close control of water content or density or both in compacting a given soil in the field. These plots permit interpolation of the strength of compacted soils for any given moulding water content and density within the range of values covered in the family of curves.

Having the complete picture of the soil strength behaviour with variation in water content and density, the limiting values of water content and density to be specified for field control may be established with confidence. These limiting values can be established from the curves of the centre or right-hand plot as indicated by the shaded area of the centre plot of Fig. 1. Having established these limits, they can then be indicated, as in the shaded portion, on the water content-density plot at the left. This simplifies the field control, since all that the inspector needs to do now is to make simple water content and density determinations to make sure that the soil from the compacted fill is staying within the shaded portion of the moisture-density plot.

In view of the preceding remarks, the question will no doubt arise in the minds of some engineers as to how well the properties of laboratory-compacted samples duplicate the properties of the soil as it is compacted in the field. While the primary purpose of this paper is to describe a test procedure and a method of data presentation for compacted soils regardless of the method of compaction that is used, the authors would like to touch briefly on the subject of the relation of strength and compaction characteristics of field-compacted soil to laboratory-compacted soil. This problem is one of increasing importance to engineers concerned with the use of earth as a construction material, and has received considerable attention at the Waterways Experiment Station in recent years.*

The Corps of Engineers has been using for some

(Continued on page 40)

*Chief, Soils Division, Waterways Experiment Station, Vicksburg, Miss.

From the Journals of the technical institutions and other material published in the Press of the World

Fluctuations in Surge Chambers

The Hydraulic Laboratory attached to the Polytechnical School of the Lausanne University is at present perfecting a new experimental method for investigating stability in surge chambers. In the course of this research MM. Cuénod and Gardel have been led to work out a new system of regulation which consists in making electric power temporarily dependent on hydraulic pressure.

This subjection of electric power to hydraulic pressure can be achieved in practice in many ways. Instead of measuring manometric pressure it may be preferable, for practical reasons, to measure the water

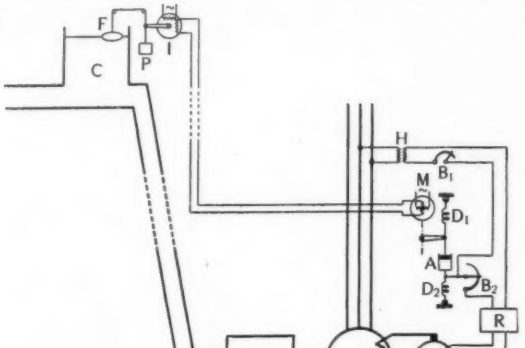


Fig. 1. Diagrammatical arrangement of a regulation system in which voltage is subjected to the control of hydraulic pressure

C = surge chamber; T = turbine; G = generator; E = exciter; R = voltage governor; B_1 = rheostat for adjusting by hand the prescribed voltage; B_2 = rheostat for adjusting the prescribed voltage in function of hydraulic pressure; H = transformer; F = float; P = counterweight; I = induction governor; M = motor drive; D_1 = counter-spring; D_2 = return spring; A = damper

level in the surge chamber, and transmit it by means of a convenient relay system. The appended diagram gives an example of an arrangement in which the voltage is subjected to hydraulic pressure.

In this arrangement, generator *G*, actuated by turbine *T*, is excited in a perfectly normal manner by exciter *E* which, in its turn, is actuated by the voltage regulator *R*. The required value of the voltage can be adjusted by hand by means of rheostat B_1 and, in function of the hydraulic pressure, by rheostat B_2. The water level is measured by float *F*, provided with counterweight *P*. The float controls the induction regulator *I*, the secondary tension of which thus becomes a measuring agent of the water level. This secondary tension is applied to the motor *M*, submitted to the counter-action of spring D_1. This motor actuates the mobile contact of rheostat B_2 by means of damper *A*. Owing to the action of return spring D_2 this mobile contact is brought automatically to its median position as soon as the hydraulic pressure remains constant. In the event, for instance, of a head loss, the turbine closes its inlet gate under the action of the speed governor. The rise of the water level in the surge chamber would force the turbine to close its inlet gate still further, and would involve the risk of bringing about an unstable regime. The rise of the water level pulls float *F* upward, and shifts the rotor of induction governor *I*; this results in a variation of the travel of motive system *M* and of the mobile contact of rheostat B_2, so that both voltage and electric load are temporarily reduced. The closing of the turbine, which might have been caused by the rise of the water level, is thus reduced in extent or altogether prevented, and the cause of fluctuations in the surge chamber is suppressed. Thanks to the co-ordinated operation of damper *A* and return spring D_2, the subjection of voltage to pressure is only temporary. The tension is therefore independent of permanent pressure fluctuations which may occur as the pressure on the turbine varies.

This system of regulation can also be applied by making the frequency dependent on hydraulic pressure.

The authors claim that, if temporary differences of voltage or frequency of 1 to 2 per cent. are tolerated it is possible, with such an arrangement, to reduce the horizontal cross-section of the surge chamber by at least 50 per cent., and to obtain a stable regulation even in the unfavourable case of the power plant supplying an independent system. *(M. Cuénod and A. Gardel. "Bulletin Techniaue de la Suisse Romande," Vol. 76, No. 16, 12.8.1950, p. 209, 9 pp., 7 ff.)*

Pipe Flow Characteristics

It is customary, in teaching elementary hydraulics and fluid mechanics to treat pipe flow, at first, as if the velocity were uniform over the whole of the cross-section; at a later stage theories of fluid friction are introduced, but very few text-books attempt to correct the initial assumptions completely by explaining these theories.

The author of this article, Lewis F. Moody, Emeritus Professor of Hydraulic Engineering, Princeton University, reviews the effect of the actual velocity distribution in a straight uniform pipe with established regime of flow on the velocity head, momentum, and the relation between mean and maximum velocity. Particular stress is laid upon the "pipe factor," i.e., the mean-to-maximum velocity

ratio. With the help of the Prandtl-Karman analysis of turbulent flow, the use of this factor is expounded

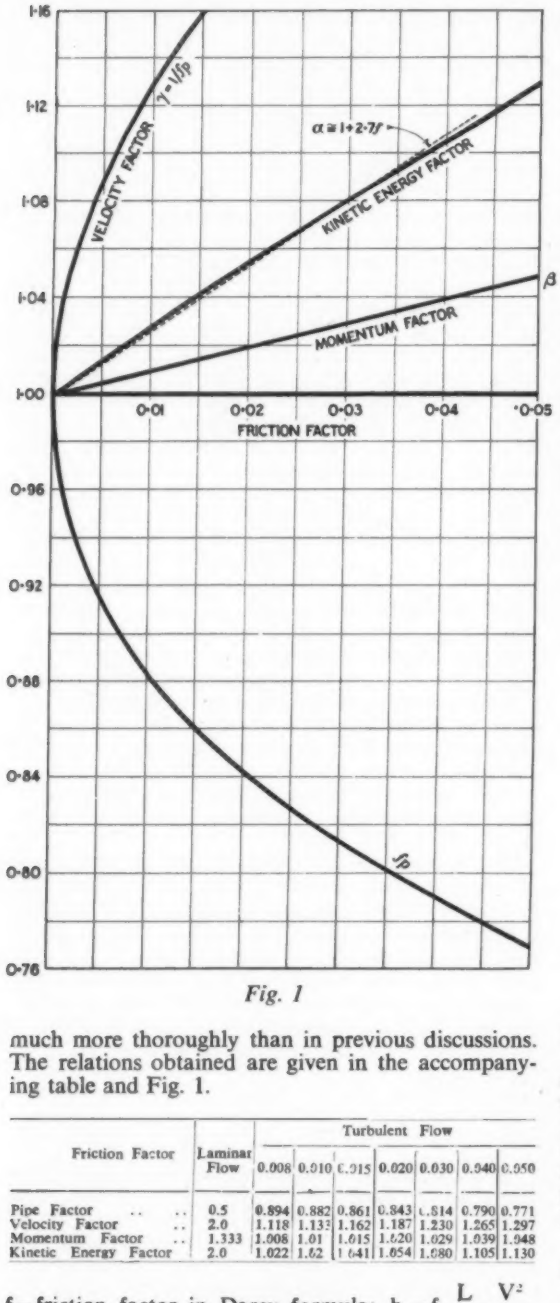


Fig. 1

much more thoroughly than in previous discussions. The relations obtained are given in the accompanying table and Fig. 1.

Friction Factor	Laminar Flow	Turbulent Flow						
		0.008	0.010	0.015	0.020	0.030	0.040	0.050
Pipe Factor	0.5	0.894	0.882	0.861	0.843	0.814	0.790	0.771
Velocity Factor ..	2.0	1.118	1.133	1.162	1.187	1.230	1.265	1.297
Momentum Factor ..	1.333	1.008	1.01	1.015	1.020	1.029	1.039	1.048
Kinetic Energy Factor	2.0	1.022	1.62	1.041	1.054	1.080	1.105	1.130

f = friction factor in Darcy formula: $h_f = f \frac{L}{D} \frac{V^2}{2g}$

f_p = pipe factor $= \frac{\text{mean velocity}}{\text{maximum velocity}} = \frac{V}{V_{max}}$

$= \frac{1}{1+1.326\sqrt{f}}$

$\gamma = \frac{1}{f_p} = \frac{V}{V_{max}} = \frac{1}{f_p} = 1+1.326\sqrt{f}$

β = momentum factor $= \frac{2}{V^2 r_o^2}\int_0^{r_o} v^2 r dr$

$= 1+\frac{5}{9}(\gamma-1)^2 = 1+0.977f.$

Impulse or reaction of jet issuing from pipe $= \beta = \frac{wQV}{g}$

α = Kinetic energy factor $= \frac{2}{\sqrt[3]{r_o^2}}\int_0^{r_o} v^3 r dr = 1 + \frac{2}{3}(\gamma-1)^2\left(\frac{7}{2} - \gamma\right)$

$\alpha = 1+2.93\ f - 1.55\ f3/2.$

$\alpha = 1 - 2.7\ f$, a very close approximation.

Velocity head of established pipe flow $= \alpha V^2/2g$.

Dealing finally with the approximate measurement of Pipe Flow the author proposes and formulates a modification of the method first discussed by Folsom and Iversen at the 1948 Annual Meeting of the A.S.M.E., and subsequently included in the "A.S.M.E. Power Test Code for Hydraulic Prime Movers," 1949 Edition, para. 147. A single central pitot tube of the type described in this Code is installed (s. Fig. 2). Two differential gauges, combined in a three-column gauge connected to three points, are used; one of the differential gauges gives the differential head h_T between the pitot tube and a wall piezometer at the same section, while the other gives the friction head h_f between the same wall

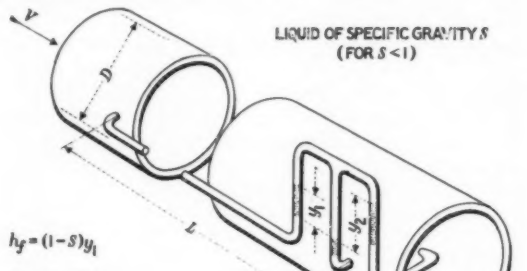


Fig. 2

piezometer and another located L feet upstream.

The proposed method should be useful whenever a close approximation is sufficient in measuring discharge. It avoids the mechanical complication of installing traversing pitot tubes, as well as the time-consuming process of taking the many readings needed when the complete velocity curve is measured. (Lewis F. Moody, "La Houille Blanche," Vol. 5, No. 3, May-June 1950, p. 313, 12 pp., 2 ff.)

Openings in Concrete Dams

Openings in concrete dams have long presented hydraulic engineers with a troublesome problem. To counteract the stress concentrations occurring in the vicinity of these openings the usual procedure in the past was to reinforce for tension at their top and bottom while providing compression steel at the sides. In the light of recent experimental research

and observations on existing dams it now seems assured that the plasticity of the concrete tends to relieve the stresses at high concentration points, and that the average unit compressive stress at failure is about equal in both solid and perforated concrete specimens.

All available data bearing on this subject were examined in connection with the design of Pine Flat Dam, on Kings River, Cal., the highest concrete gravity structure yet undertaken by the U.S.A. Corps of Engineers. The purpose of this article is to present a summary of factors believed to influence stresses developed around openings in this dam, and the resultant conclusions as to where steel should be placed around such openings in that structure.

Pine Flat Dam has the following main characteristics: The straight gravity structure, provided with a gate-controlled overflow spillway, is roughly 440 ft. in height and 1,820 ft. in length at the crest; it will be divided into 50 ft. monoliths by transverse construction joints. The cross-section will be roughly triangular in shape, with the upstream face vertical throughout above El. 905, and battened 1 to 0.05 below this point. The slope of the downstream face in general will be 1 to 0.78. The overflow section will be somewhat heavier than the non-overflow section. The overflow spillway, 292 ft. long, will be controlled by six 42 × 38 ft. radial gates. For flood control and irrigation releases, and for sluicing, there will be ten 5 × 9 ft. conduits in the overflow section, arranged in two corresponding rows with centres at El. 570.0 and El. 740.0 respectively.

Conduit entrance openings at the upstream face will be rectangles 8 ft. 4 in. by 15 ft. in size, reducing to the 5 × 9 ft. section 9.0 ft. downstream from the entrance. Each outlet will be controlled by a 5 x 9 ft. sliding service gate operated from the gate chamber over the gate by a hydraulic cylinder. An identical 5 x 9 ft. gate will be placed 8 ft. upstream from each service gate for emergency use. An additional emergency closure of the conduit entrance at the upstream face will be provided by the fixed wheel type structural steel gate 8 ft. 4 in. by 15 ft. In the initial construction, provision for power facilities that may be installed later will be limited to three 13½ ft. steel penstocks passing through the main body of the dam, closed for the present by hemispherical bulkheads. At each penstock intake there will be trashracks, transition from trashracks to two rectangular sections for the stop-log gates and service gates respectively, and transitions from the rectangular to circular sections.

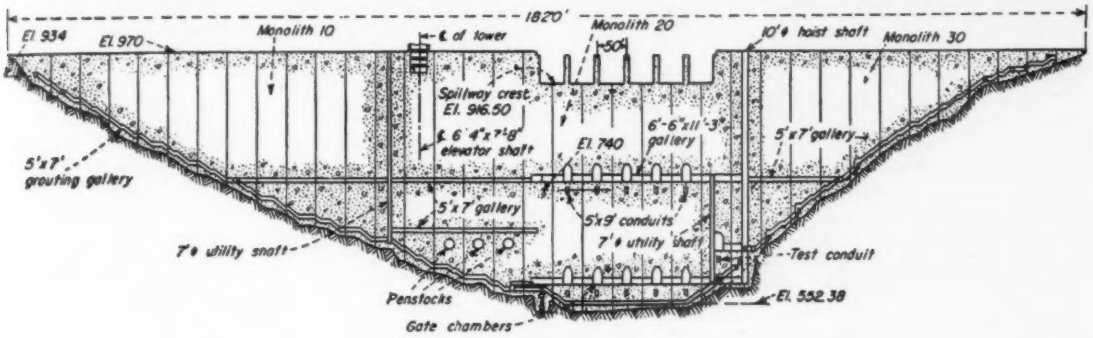


Fig. 1

In addition to the openings mentioned above a system of galleries, adits, chambers, and shafts will be provided within the body of the dam to ensure access and space for the operation and maintenance of accessories and utilities. A 5 x 7 ft. grouting gallery consisting of a series of stair flights and horizontal passages, will furnish access for the grouting of the foundation cutoff curtain, and will collect drainage from the foundation and from the drainage curtain in the body of the dam. Two horizontal access galleries at El. 584 and 754, will extend the full length of the dam. In addition to connecting together the grouting galleries in both abutments, these galleries will give access to ten gate chambers, five in each level, for the operation of the 5 x 9 ft. sluice gates. A further gate chamber at El. 639 will enable the 5 by 9 ft. slide gate in the test conduit to be operated. Six adits will ensure access from the downstream face to the grouting galleries. In addition to the galleries and chambers, vertical shafts and wells will be

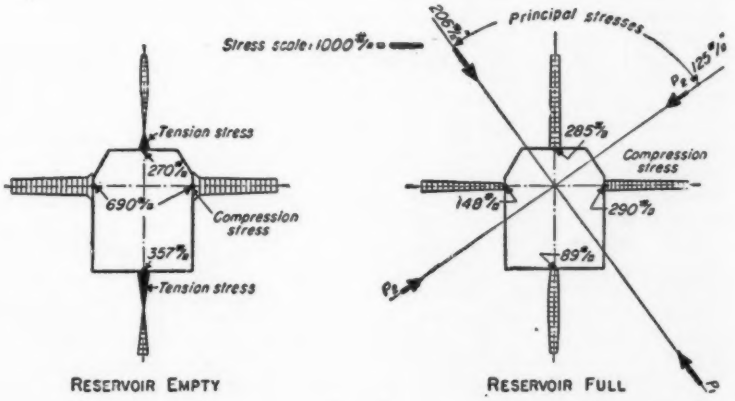


Fig. 2

provided for various purposes. For example, a 10 ft. hoist shaft extending the full height of the dam; a smaller shaft for a passenger lift will extend from the top of the dam to El. 620; two 7 ft. utility shafts for electrical conduits, pipes, and an emergency ladderway. A 42 in. shaft will serve the recording float gauge.

For galleries and chambers running parallel to the axis of a gravity dam near its upstream face, two principal conditions of stress can exist, according as the reservoir is empty or full. In the case of the " reservoir full " condition, the water pressure on the face of the dam will produce the lateral compression which counteracts the tension stress at the top and bottom of the opening. Stress distribution around the gate operating chamber is shown in diagram Fig. 2 for the two extreme conditions of loading.

In the case of openings running at right angles to the body of the same, such as the adits, water release outlets and penstocks of the Pine Flat Dam, there is no appreciable change in the pattern of stress between " reservoir empty " and " reservoir full " conditions, but the intensity and inclination vary with the load. Openings of this type are usually subjected to a vertical or inclined compression stress producing tension at top and bottom of the opening and a concentration of compression at the sides. The adits themselves present no particular structural problem ; the water release outlets, in addition to gravity induced stresses, will be subjected to the internal hydrostatic pressures ; the 13½ ft. openings for the penstocks represent a 27 per cent. reduction in the load bearing area of the 50 ft. monolith involved, and tends to destroy its structural integrity.

The U.S. Bureau of Reclamation Structural Research Laboratory carried out an extensive range of tests and studies on the influence of openings in concrete upon its bearing capacity, and proved that the plastic flow of concrete relieves high-load stress concentrations. The conclusions as to where steel reinforcement should be placed around the openings provided in the Pine Flat Dam are given as follows :

(1). On the evidence of observations on openings in existing dams and of laboratory tests on pierced concrete blocks, no compressive reinforcement will be provided at any openings; these observations and tests have shown that the high compressive stress concentrations indicated by the elastic theory do not develop at the side of openings.

(2). Tensile reinforcements will generally be omitted at all openings parallel to the axis of the dam in the upstream third of the dam, since at " reservoir full " condition the lateral water load will tend to close the small cracks (less than 0.01 in.) which may have developed at top and bottom under " Reservoir empty " condition, and reduce the tensile stresses at these spots.

(3). Reinforcement will be provided at all unlined openings subject to internal water pressure in order to resist the total tension developed at the perimeter by internal water pressure. There will be no reinforcement at the sides of openings where compressive stresses equal or exceed the tensile stresses developed by the internal water prssure.

(4). At all lined openings subject to internal water pressure bar reinforcement will be provided to resist 90 per cent. of the total tension where the lining is not able to take the entire tensile load. Where the lining is strong enough, e.g. a pipe, to resist the full hydrostatic internal pressure, no reinforcement will be provided unless needed to ensure the structural integrity of the monolith, and to prevent the formation of injurious cracks. Specifically this condition prevails around the penstock linings.

Applied to the design of the Pine Flat Dam, this analysis permitted an economy of about 2,000,000 lb. of steel reinforcement around the openings, as compared with the conventional design usually applied to a structure of this type. *(John B. Alexander and D. B. Gumensky, " Engineering News-Record," Vol. 145, No. 10, September 7, 1950.)*

Care of Hollow Steel

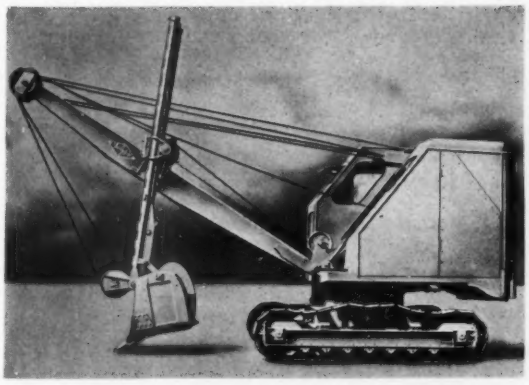
The introduction of the jack-hammer and other powerful drilling tools brought about the development of strong steels to withstand the severe impact and fatigue of high-frequency blows. In a modern hammer, these blows are delivered at a rate of 1,800 to 2,000 strokes per minute, and each blow is struck with up to about 185 ft.-lb. of energy. Other developments, such as the machine sharpener and the detachable bit, also required modifications in the metallurgy of forging and use of the drill steel. Modern drill steel is capable of being hardened to produce tough and abrasion-resisting cutting edges on a bit which is forged integral with the rod. It also possesses tough, fatigue-resisting shanks and bit-connections. In order to maintain the usefulness in life of drills and to cut drilling costs, it is of first importance to avoid improper drilling. This refers in all types (drifting, downhole and stoper) to bad alignment of drill-rod with machine, loose machine set-up, and improper feed-pressure on the drill-rod. A hollow drill-rod is intended and designed for percussion drilling. Best drilling efficiency depends on the force of the hammer-blow to the bit in a straight line. When the drill-steel is forced out of alignment, stresses in the rod are increased enormously and cause failures. These and similar errors are inevitably aggravated by worn machine parts. Maintenance of the drilling machine has therefore direct influence upon drill-life. Improper air pressure is also likely to cause damage to the drill. Working at too low a pressure results in the drill-rod absorbing hammer-energy that is ineffective in cutting rock. High air pressure, on the other hand, increases drilling speed at the expense of drill-rod and bit life. In use, even with excellent drilling conditions, hollow steel drills are subjected to very high stresses each time they are struck. If there are deep tool marks or dents on the surface the stresses are concentrated at the damaged spot. Proper forging and heat treatment of the drill steel are, perhaps, even more important. Most of the failures in collared or lugged shanks can be traced indirectly to improper forging or heat-treating techniques. The standard shop annealing method of slow cooling in some insulating material can be entirely satisfactory, provided precautions are observed. Some practical suggestions are made how to get best results in forging operations, in annealing and in avoiding cracks and laps. — *W. H. McCormick and C. W. Derby. Engineering and Mining Journal, Vol. 151, No. 6, p. 74; 3 pp.; 7 ff.*

New Blaw Knox Excavator

Blaw Knox Limited have recently put on the market a new ½ cu. yard capacity excavator designated the "BK-Fifty." It is a fully revolving excavator and will dig and dump in any direction, its quick convertibility making it a versatile item of equipment for general excavation purposes, building construction and road works. A claim is made that its compact design and short tail radius make it particularly suitable for working in confined spaces. The accompanying illustrations show the machine arranged as a drag line excavator and with the face shovel attachment.

A Perkins P6 6-cylinder diesel engine developing 52 b.h.p. at 1,500 r.p.m. on a 12 hours continuous rating is fitted as standard. Power is transmitted through a Borg & Beck 14 in. single-plate automotive type clutch to a two-speed gearbox, and the final drive is by roller chains. Travelling speeds are 0.84 m.p.h. in low gear and 3.4 m.p.h. in top gear. All gears are mounted on ball bearings and run in oil. The fuel tank capacity is 35 gallons and efficient filters are incorporated into the fuel system. Electric starting is provided, with auxiliary hand starting and Ki-gass priming system.

All controlling hand levers and pedals are grouped within easy reach of the driver. A commendable feature is the individual control of each crawler track by a hand lever which gives easy and fast manoeuvring. A comfortable adjustable driving seat is provided and maximum visibility is afforded under all working conditions by the provision of large toughened-glass windows and an adjustable windscreen. The accompanying table gives the leading dimensions and particulars.

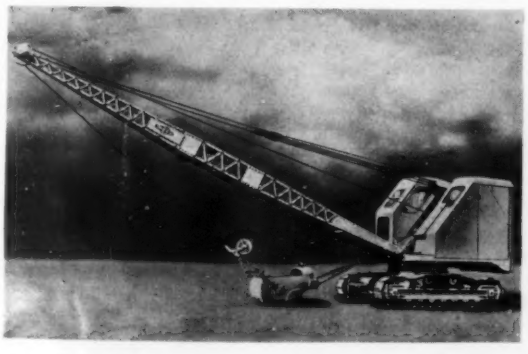


Showing the excavator with the face shovel attachment

Model	Capacity cu. yds.	Power Unit		Rope Dia.		Crawlers			*Ground Bearing Pressure lbs. per sq. in.	Ground Clearance	Dimensions		Approx. Weight of Excavator without Attachment lb.
		Type	H.P.	Hoisting	Boom Hoist	Width of Shoe	Overall Width	Overall Length			Cab Height	Cab Width	
"BK-FIFTY"	½	6 Cylinder Diesel Engine	52 at 1500 r.p.m.	(2) 5/8in.	¼in.	15in.	8ft. 0in.	9ft. 10in.	8.4	15in.	9ft.11in.	7ft. 0in.	20,700

*With Drag Shovel Attachment.

The boom for the drag shovel is of electrically welded, box-section construction with a length of 15 ft. 8½ in. between pin centres. The bucket arm is constructed of heavy bar section 8 ft. 7 in. long and is pivoted to the boom. A 30 in. bucket is standard but optional buckets of 24 in. and 36 in. can be supplied.



The "BK-Fifty" excavator with drag line attachment

For the face shovel the boom is also of welded, box-section construction. The bucket arms are of steel tube with high tensile steel racking electrically welded on to it. A cast steel saddle block on the boom holds the dipper stick rack in mesh with two pinions on a splined shaft. Independent crowding assures a full bucket at every swing and the bucket door design affords a large opening for speedy discharge. Maximum operating radii at crawler tread level with the boom at 45° are as follows: dumping radius 18 ft. 6 in.; dumping height 13 ft.; cutting height 19 ft.; clean up radius 14 ft.

The boom for the dragline, of riveted lattice construction, has a standard length of 30 ft., but 5 ft. and 10 ft. extensions can be added up to a maximum of 40 ft. The same boom is used for the grabbing crane or crane applications. With a 30 ft. boom and a 19 ft. depth, a digging radius of approximately 34 ft. can be obtained; with a 40 ft. boom and 18 ft. depth the digging radius is 47 ft.

The boom for the crane is 30 ft. long but 5 ft. and 10 ft. extensions can be added up to a maximum of 50 ft. The same boom is used for dragline and grabbing crane applications.

The lifting crane equipment includes a 5½ ton single sheave crane block, the weight of which must be included in the total lifted load. A tagline is provided and load indicator; the maximum load is 5½ tons.

A New Single-Tool Compressor

THE Atlas Diesel Co. Ltd. announce the production of a new single-tool portable air compressor, the type NT7-DV, which departs from usual practice inasmuch as both the diesel engine and air compressor are air cooled, thereby avoiding the necessity for cooling water with its attendant troubles in winter and cold climates. It is an angle-type, two-stage machine, both connecting rods operating from the same crankpin of the hardened drop-forged crankshaft, and all moving parts are carefully balanced to ensure a minimum of vibration. Force-feed lubrication is provided to main, big-end and gudgeon-pin bearings.

View of the compressor with one of the side curtains in the raised position

The bores of the low and high-pressure cylinders are 160 mm. (6¼ in.) and 95 mm. (3¾ in.) respectively, and the common stroke is 78 mm. (3 in.). The suction and delivery valves are of the light-weight sprung-disc type. Air cooling is effected by means of a flywheel-type fan, operating in a volute casing, which draws air along the compressor crankcase, thereby assisting in oil cooling, and then passes the air through an intercooler. Intake air is cleaned by a Vokes HD-5 dry air filter.

The compressor, which is designed for normal operation at 100 lb. per sq. in., has a piston displacement of 78 cu. ft. per min. when running at 1,400 r.p.m. and delivers approximately 63 cu. ft. of air per min. at this pressure, measured in accordance with the regulations laid down in B.S.S. No. 726.

The power unit is a two-cylinder, air cooled, diesel engine manufactured by Armstrong-Siddeley Motors Limited. The cylinders have a bore and stroke of 4¼ in. × 4¼ in., and the engine develops 20 b.h.p. at 1,400 r.p.m. It is cold starting and has direct injection, provided by a standard C.A.V. fuel pump and injectors. The finned cylinders and cylinder head are directly air cooled by air from the vaned flywheel. The cooling air first passes through tubes placed longitudinally through the crankcase, providing effective oil cooling. Air and oil filters ensure protection under the most adverse conditions.

The drive transmission from the engine to the compressor is effected through a "Flexaire" automatic centrifugal clutch, which is claimed to give long service without maintenance or adjustment. The fuel tank has a capacity of 5½ gallons, sufficient for eight hours' continuous working. A 36 in. long by 15 in. dia. welded air receiver is provided with a relief valve, a drain tap, and two ¾ in. outlet cocks, fitted with Atlas "Quick Grip" couplings.

The unit is mounted on a welded R.S. section steel chassis, provided with a sprung axle and two pneumatic-tyred road wheels, complete with mudguards. A welded box-type drawbar is provided and carries a retractable support leg and hand bars to facilitate manoeuvring on site. Full parking and over-run braking equipment is provided to conform strictly to current Road Traffic Act Regulations for towing up to a maximum speed of 20 m.p.h. A practical feature is the non-detachable side curtains, which when open, are folded neatly upwards, and can be locked in the closed position to form a modern streamlined appearance. An equivalent petrol-engine-driven compressor is also available, the power unit being a "Standard" 22½ h.p. four-cylinder machine.

This equipment forms a valuable addition to the range of Atlas products and meets a demand for a highly mobile unit capable of operating one heavy-duty concrete breaker or two light pick hammers or clay diggers.

From page 34

time the dynamic (Proctor) method of compaction for design and control work in the laboratory on earthen embankments of all types and military airfields. Investigations performed in the past have indicated a preference for dynamic compaction over static compaction. Present indications are that dynamic compaction cannot be relied upon consistently to duplicate field characteristics. It also appears, and logically so, that the strength characteristics of some soils are influenced more than others by the method of compaction. Soils investigated thus far indicate that the agreement between field and laboratory for maximum shear strengths is fairly good and is better than the agreement for modulus of deformation. In other words, when laboratory samples are compacted dynamically and compared with field compaction, the differences in maximum shear strength, in general, are not sufficient to cause a great deal of alarm, but the differences in moduli of deformation appear to be large enough to cause concern. In pavement design where the allowable deflections are small, the stress at low strain becomes a major consideration and it becomes of paramount importance to duplicate the field stress-strain curve in the laboratory. In the reverse, it appears that allowable deflections in earthen embankments are not so critical and, consequently, based on the limited investigation to date, the correlation between the laboratory and field is sufficiently good not to cause undue concern. However, further investigation of this problem of laboratory duplication of the strength properties of the prototype definitely is needed.

Westinghouse *puts rivers to work . . .*

producing low-cost electric power for industry and homes

For more than 50 years Westinghouse has been building hydroelectric plants to harness the power of mountain rivers in all parts of the world. Designed in cooperation with leading engineering consultants and constructed through the broad technical knowledge and extensive manufacturing facilities of Westinghouse, these projects are placing low-cost electric power at the service of many industries such as cement and fertilizer plants, textile mills and sugar refineries. In addition to creating jobs through expansion of industry, Westinghouse hydroelectric installations are contributing to a better way of life for people everywhere by putting electricity to work in the home for greater comfort and convenience.

- ***Grand Coulee Dam, U. S. A.***—supplies water to irrigate 1,200,000 acres . . . 18 Westinghouse generators produce nearly 2,000,000 kilowatts.
- ***Avanhandava, Brazil***—one of the most modern hydro plants in South America . . . utilizes 3 Westinghouse 35,000 kva outdoor-type generators.
- ***Ixtapantongo, Mexico***—important project in Mexico's power program . . . two Westinghouse 31,000 kva generators have been installed.

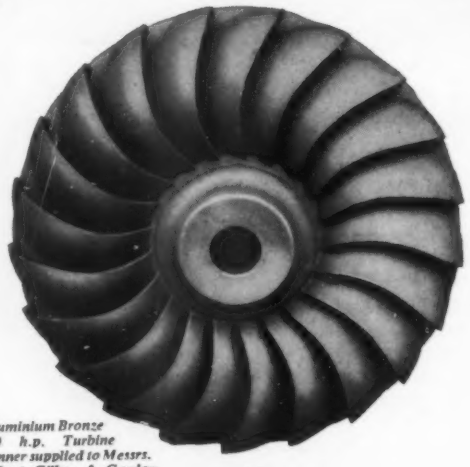
Westinghouse offers a complete service in cooperation with leading engineering consultants in designing hydroelectric plants and supplying all components from hydraulic gates and valves for irrigation and flood control to generators and substations for the production and distribution of power.

WESTINGHOUSE

Westinghouse

WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

40 Wall Street, New York 5, U. S. A.



Aluminium Bronze 180 h.p. Turbine Runner supplied to Messrs. Gilbert Gilkes & Gordon Ltd., of Kendal, England

BIRSO TRADE MARK

HIGH TENSILE

ALUMINIUM BRONZE

CASTINGS

for

WATER POWER INSTALLATIONS

possess a Tensile Strength of 45 tons per sq. in., have a specific gravity of only 7.5 and are guaranteed to withstand any hydraulic pressure; also highly resistant to erosion, corrosion and abrasion.

We are specialists in all kinds of Non-Ferrous Castings — in PHOSPHOR BRONZE, GUN-METAL, MANGANESE BRONZE, ETC. and in Light Alloy Castings, Chill-Cast Phosphor Bronze Rods and Tubes, Precision Machined Parts, etc.

Fully approved by Admiralty and A.I.D.

B104

T. M. BIRKETT & SONS. LTD.
HANLEY · STAFFS
'Grams: Birkett, Hanley 'Phone: Stoke-on-Trent 2184-5-6

in association with

BILLINGTON & NEWTON LTD.
LONGPORT, STOKE-ON-TRENT
'Grams: Bronze, Phone, Longport 'Phone: Stoke-on-Trent 87303-4-4,88147

Specify

MICHELL BEARINGS

AND MAKE SURE OF YOUR

THEY 'SET THE COURSE' FOR ENDURING RELIABILITY

for Hydro Electrical Installations, Turbine Thrusts, Pedestal Bearings, Motors, Generators, Pumps (Vertical and Horizontal), Fans, Paper-Making and Extruding Machines, etc.

MICHELL BEARINGS

SOUTH BENWELL NEWCASTLE upon TYNE

Telegrams: MICHBEARO Telephone: 34279

Is it Deck, Bulkhead or Tank Top?

FROM a welding point of view it is of little concern whether the work is decking, bulkheads or tank tops, because the modern automatic process can handle it all with far greater economy than manual welding. Miles of this class of welding are being carried out regularly with Fusarc machines, not only on decking but also for derrick posts, masts, 'tween deck pillars, etc. Write today for more details of this economic process.

If you have a problem concerned w the manufacture of BOILERS, GIRDE STEEL MASTS, STEEL DECKING, PIP TUBES, TANKS, WHEELS, SHAFTS e we shall be happy to advise you fabrication by welding. Meanwhile, can assure you that whatever you m be making by welding, if it's a suit application—

You make more at less cost by

FUSARC WELDIN

IT'S AUTOMA

FUSARC LTD., Dept. M.738, TEAM VALLEY, GATESHEAD-ON-TYN

Metering and Control . . .

BROWN BOVERI

Control room at La Dernier hydro-electric power station of the Compagnie vaudoise des forces motrices des lacs de Joux et de l'Orbe, Lausanne, Switzerland.

All changes in operating conditions, e.g., position of circuit-breakers, are confirmed on the dummy board which is arranged with relay and control panels on either side of it.

CONTROL ROOMS

with or without luminous diagrams for electricity supply and industrial plants meet all possible requirements and facilitate the duties of the operator.

Let us know your problems. We shall be only too pleased to advise you.

BROWN, BOVERI & CO.
LIMITED
BADEN (Switzerland)

CEMENT for Hydro-electric schemes

ANNUAL OUTPUT
3.000.000 TONS

31 WORKS
THROUGHOUT ITALY

CENTRAL LABORATORY
FOR RESEARCH ON
CEMENT & CONCRETE

Cement complying with BSS No. 12/1947

Special low heat cement for dams

White cement

Special pozzuolanic cement for sea works

Early high strength cement

EXPORTERS TO ALL PARTS OF THE WORLD FROM THE PORTS OF GENOA, IMPERIA, SAVONA, CIVITAVECCHIA, MONOPOLI, BARI, VENICE

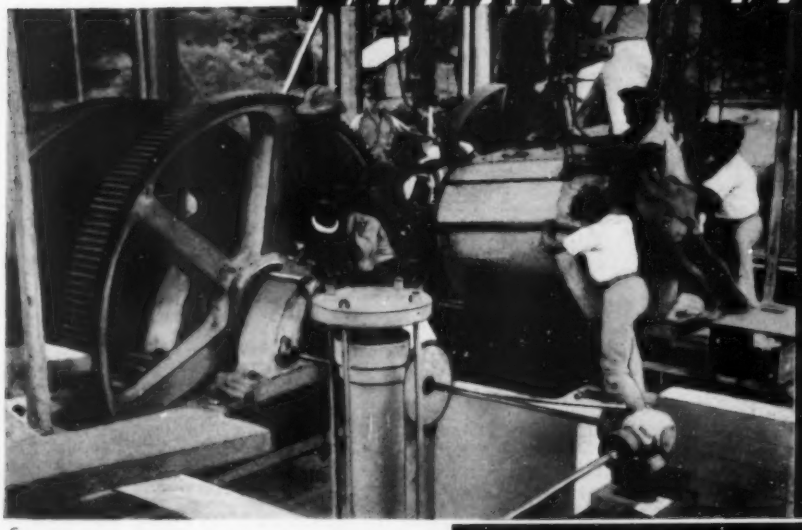
"ITALCEMENTI" Fabbriche Riunite Cemento

CAPITAL: ITALIAN LIRE 4.000.000.000

BERGAMO · · · ITALY

ADDRESS: "ITALCEMENTI," P.O.B. 147, BERGAMO (ITALY)
CABLES: ITALCEMENTI—BERGAMO

EFFICIENT HAULAGE



Hydro-Electrification Scheme—Ceylon

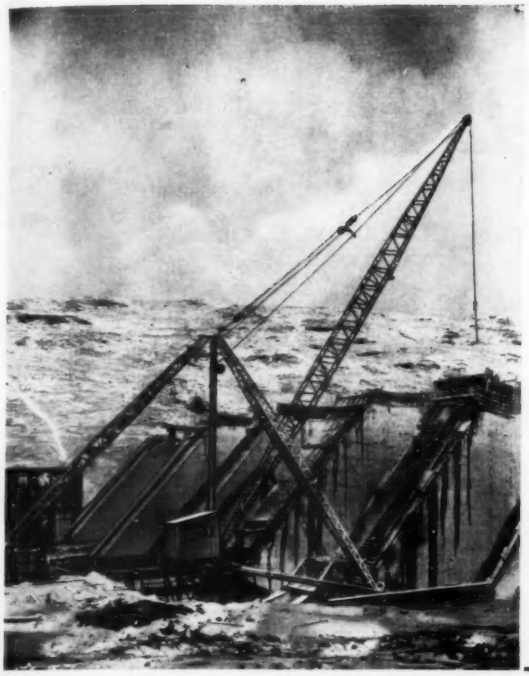
Installation of Haulage Gear at Norton Bridge

M. B. WILD & CO LTD NECHELLS BIRMINGHAM 7

Telephone EAST 2041-7

Telegrams & Cables: HAULING, BIRMINGHAM

ANDERSON



ELECTRIC DERRICK CRANES

OUTSTANDING FEATURES:

"Unit" Gearing
Superior Visibility
High Speed Operation
Reliability
Economy

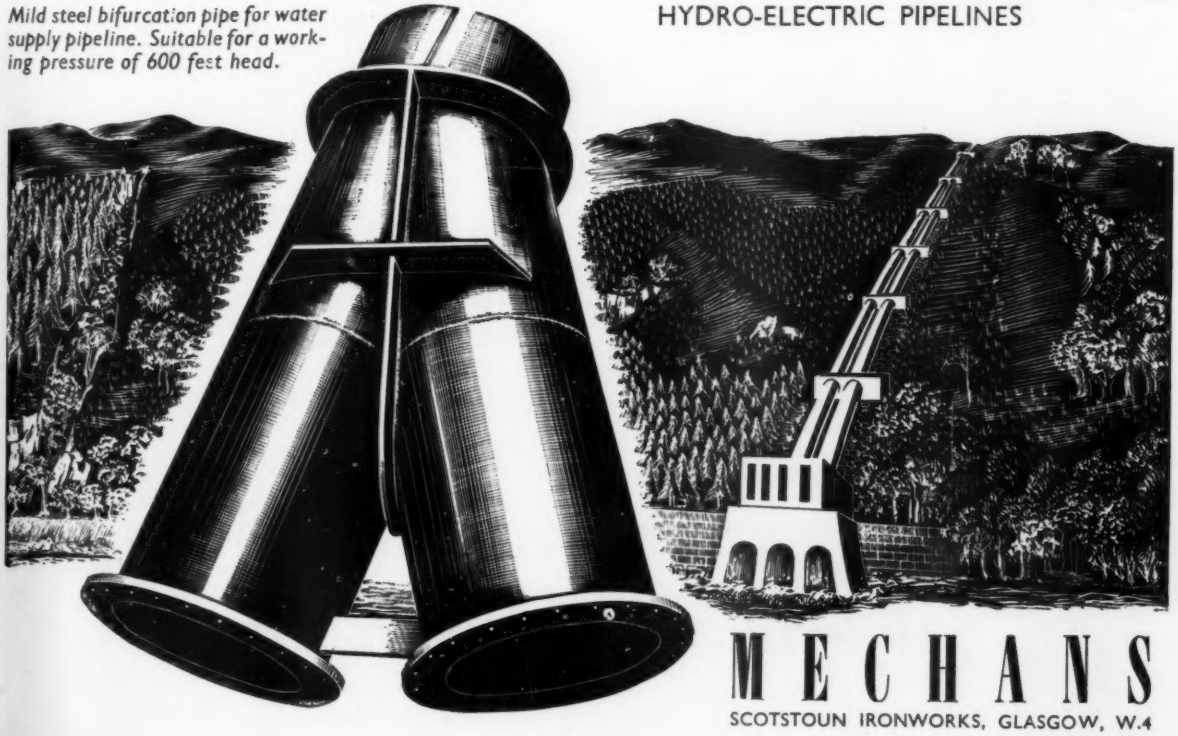
Illustration shows 7-ton Crane with 120-ft. jib on Loch Sloy Hydro-Electric project.

THE ANDERSON-GRICE CO. LTD.
TAYMOUTH ENGINEERING WORKS - CARNOUSTIE - SCOTLAND

Phone: Carnoustie 2214-5 Grams: DIAMOND, CARNOUSTIE
LONDON OFFICE: Finsbury Pavement House, 120 Moorgate, E.C.2
Phone: MONarch 4629

Mild steel bifurcation pipe for water supply pipeline. Suitable for a working pressure of 600 feet head.

HYDRO-ELECTRIC PIPELINES



MECHANS

SCOTSTOUN IRONWORKS, GLASGOW, W.4
Phone: Scotstoun 2211 *Grams: "Nautical, Glasgow"*

LONDON: 10 PRINCES STREET, WESTMINSTER, S.W.1 'Phone: WHItehall 4288

OVERHEAD HAND POWER CRANES

EXPERTS IN

VAUGHAN

CRANECRAFT

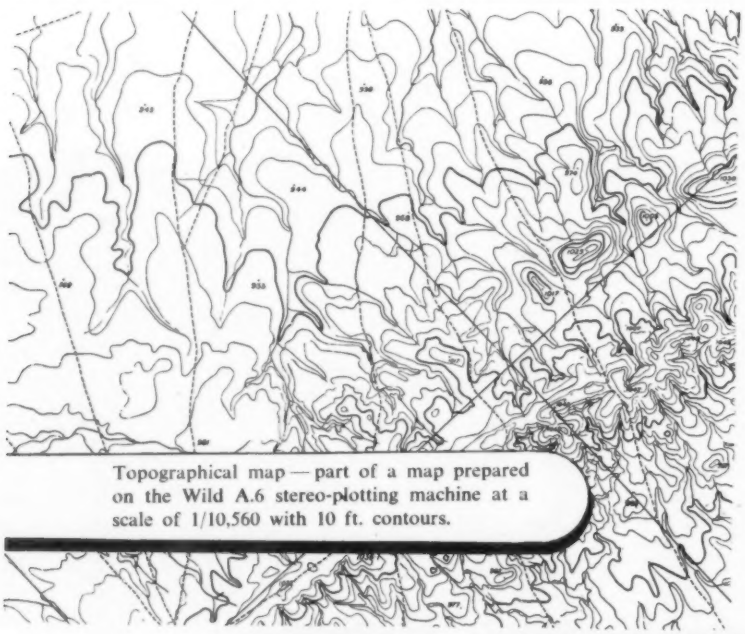
When handling loads by man-power you cannot do better than instal a VAUGHAN Hand Crane. Easy to operate, and inexpensive to maintain, these hard-wearing rugged products still find unlimited uses in modern industry

Ask for Cat. Section S.G.7. or D.G.5.

Made in Single- or Double-Girder Types and in sizes from ½ - 30 tons capacity. Roller bearing runners, high factor of safety, worm geared hoisting motion

THE VAUGHAN CRANE CO. LTD.
WEST GORTON, MANCHESTER 12.
ENGLAND.

Telephone EASt 1473.



Topographical map — part of a map prepared on the Wild A.6 stereo-plotting machine at a scale of 1/10,560 with 10 ft. contours.

WHAT AIR SURVEY CAN DO FOR YOU

As an engineer: accurate plans at scales up to 40 ft. to 1 inch.
As a town planner: contoured plans at scales up to 1/1,000 with 2 ft. contours and revised copies of existing maps.
As an architect: accurate topographical or architectural models.
As a geologist: stereoscopic air photographs, photographic mosaics and topographic maps.
All carried out rapidly and economically with the most up-to-date photogrammetric apparatus and by operators with highly specialized and varied experience.

HUNTING AEROSURVEYS LTD.

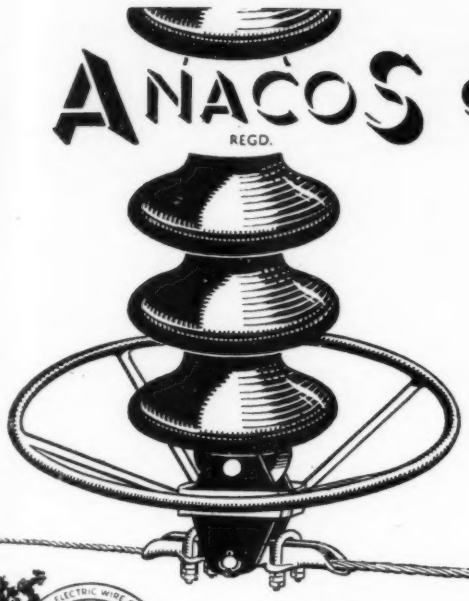
29 OLD BOND STREET, LONDON, W.1 Tel.: REGent 5211. Cables: Astereo, London.

Associated Companies in Africa, Canada, New Zealand, Australia and S. America.

130.114

ANACONDA overhead lines

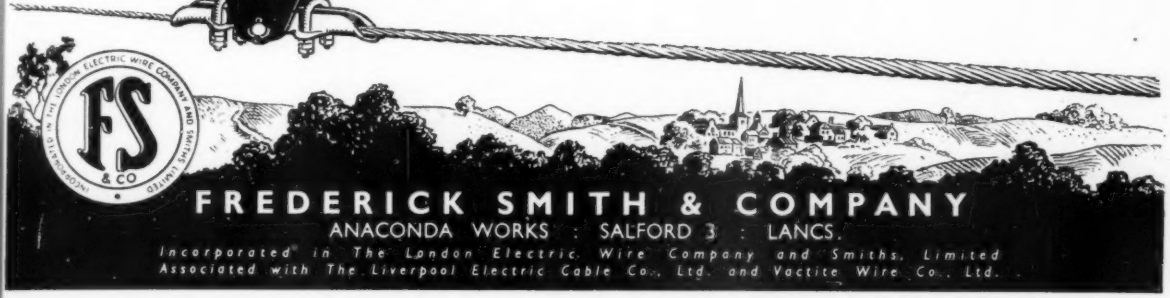
REGD.



in

Hard drawn Copper, Cadmium-Copper and Steel cored Aluminium to relevant British Standards.

We are pleased to quote to your specification.

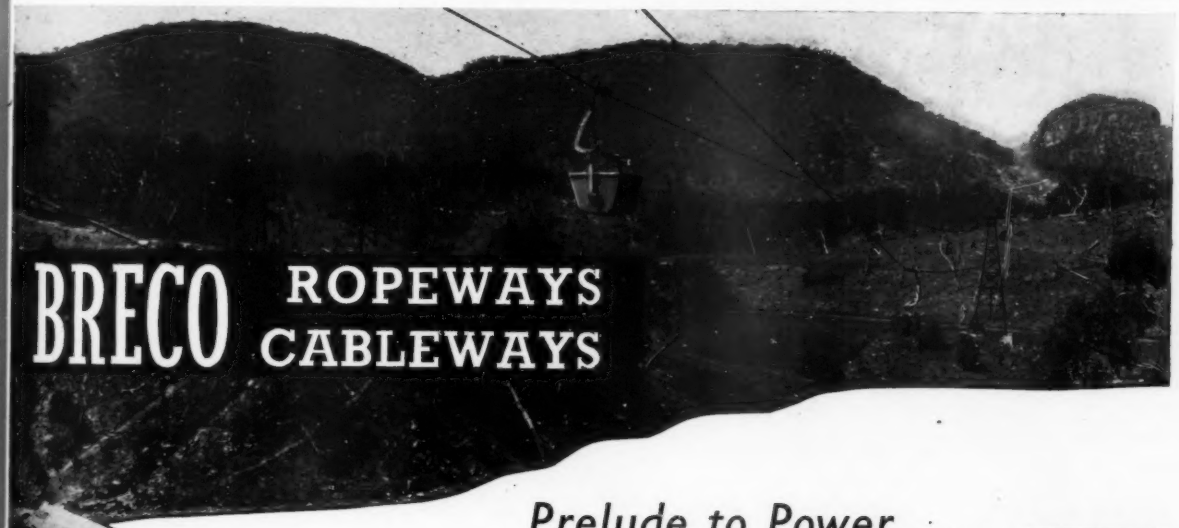


FS & CO

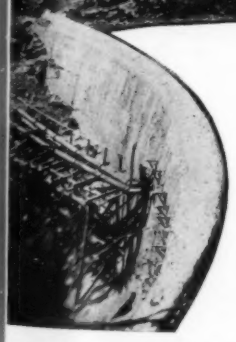
FREDERICK SMITH & COMPANY

ANACONDA WORKS : SALFORD 3 : LANCS.

Incorporated in The London Electric Wire Company and Smiths, Limited
Associated with The Liverpool Electric Cable Co., Ltd. and Vactite Wire Co., Ltd.



BRECO ROPEWAYS CABLEWAYS



Prelude to Power . . .

BRECO Ropeways and Cableways provide vital links in the chain which converts H_2O to K.V.A. Short links or long links—BRECO can build ropeways for dam building of any capacity or length, incorporating every labour saving device. Experience counts and Breco are the largest suppliers of heavy capacity ropeways in the world today. Advice and literature freely and willingly supplied.

BRITISH ROPEWAY ENGINEERING CO. LTD.

PLANTATION HOUSE, MINCING LANE, LONDON, E.C.3 **Tel. Mansion House 4681-2**

A
Allgemeine Elektricitats Gesellschaft 9
Allmanna Svenska Electriska Aktiebolaget 27
Anderson-Grice Co. Ltd. 45
Armfield Hydraulic Engineering Co. Ltd., The ... ... —
Arrol, Sir Wm. & Co. Ltd. ... ... —
Ateliers de Constructions Electriques de Charleroi 28
Ateliers de Construction Méchaniques de Vevey S.A. 33
Ateliers de Construction Oerlikon ... —
Atlas Diesel, Aktiebolaget ... ... —

B
Balfour, Beatty & Co. Ltd. ... ... —
Birkett, T. M. & Sons Ltd. 42
Blackwood, Hodge J. & Co. Ltd. ... 35
Blakeborough, J. & Sons Ltd. ... —
Blaw Knox Ltd. 32
Boving & Co. Ltd. 5
Brady, G. & Co. Ltd. 18
British Insulated Callenders Cables Ltd. 38
British Ropeway Engineering Co. Ltd. 47
British Thomson-Houston Co. Ltd. 30
Brown Boveri & Co. Ltd. 43
Bruce Peebles & Co. Ltd. 14
Butters Bros. & Co. Ltd. ... 26

C
Cementation Co. Ltd., The 25
Ceretti & Tanfani Ropeway Co. Ltd. —
Christiani & Nielsen 11
Climax Rock Drill & Engineering Works Ltd. 19
Consolidated Pneumatic Tool Co. Ltd. 29
Cooke & Ferguson Ltd. 23
Costain, Richard, Ltd. 20

D
Dominion Engineering Co. Ltd. ... 13

E
English Electric Co. Ltd., The ... ... *Back Cover*

F
Fabbriche Riunite Cemento ... 44
Firth-Vickers Stainless Steels Ltd. ... —
Fusarc Ltd. 42

G
General Electric Co. Ltd. 34
Gilbert Gilkes & Gordon Ltd. ... 10
Glenfield & Kennedy Ltd. 3

H
Hackbridge & Hewittic Electric Co. Ltd. ... ... —
Harland Engineering Co. Ltd., The 36
Henderson, John M. & Co. Ltd. ... 16
W. T. Henley's Telegraphic Works Co. Ltd. 8
Holman Bros. Ltd. ... *Inside Back Cover*
Hunting Aerosurveys Ltd. 46

K
Karlstads Mekaniska Werkstad ... —

L
LaFarge Aluminous Cement Co. Ltd. —
Lamont, J. H. & Co. Ltd. ... ... —
Les Constructeurs de Conduites Forcées ... ... —

M
MacLellan, Geo. & Co. Ltd. ... —
Mechans Ltd. 45
Metalock (Britain) Ltd. 21
Metropolitan-Vickers Electrical Co. Ltd. ... ... *Front Cover*
Michell Bearings 42
Millars Machinery Co. Ltd. ... —
Morris, Herbert Ltd. 17

N
Newport News Shipbuilding & Dry Dock Co. 31
Nuttall Edmund Sons & Co. (London) Ltd. 15
Nydqvist & Holm Akt. ... ... —

P
Pirelli-General Cable Works Ltd. ... 5
Poles Ltd. ... ... —
Pyrotenax Ltd. ... ... —

R
Ransomes & Rapier Ltd. 4
Rawlplug Co. Ltd., The ... ... —
Reyrolle, A. & Co .Ltd. *Inside Front Cover*
Robinson & Kershaw Ltd. 22

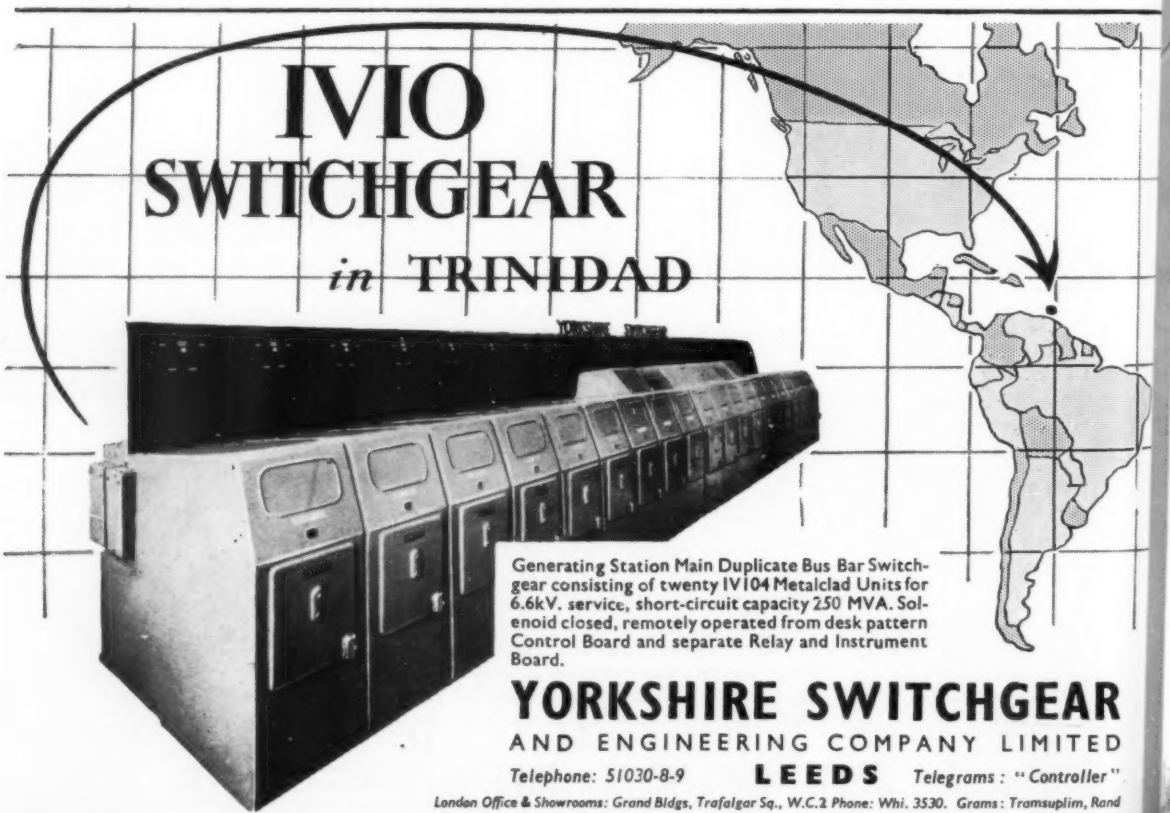
S
Smith, Fredk. & Co. 47
Smith, Thos. & Sons (Rodley) Ltd. 24
Soc. Nationale Delle Officine di Savigliano ... ... —
South Durham Steel & Iron Co. Ltd. —
Standard Telephones & Cables Ltd. —
Steatite & Porcelain Products Ltd. ... —
Stratford Products Safety Service Co. Ltd. 7

T
Taylor, Tunnicliff & Co. Ltd. ... —
Taylor Woodrow Construction Ltd. —
Teeside Bridge & Engineering Works Ltd., The ... ... —

V
Vaughan Crane Co. Ltd. 46

W
Watson, Robert & Co. (Constructional Engineers) Ltd. ... —
Westinghouse Electric International Company 41
Wimpey, Geo. & Co. Ltd. ... ... —
Winget Ltd. ... ... —
Wild, M. B. & Co. Ltd. 44

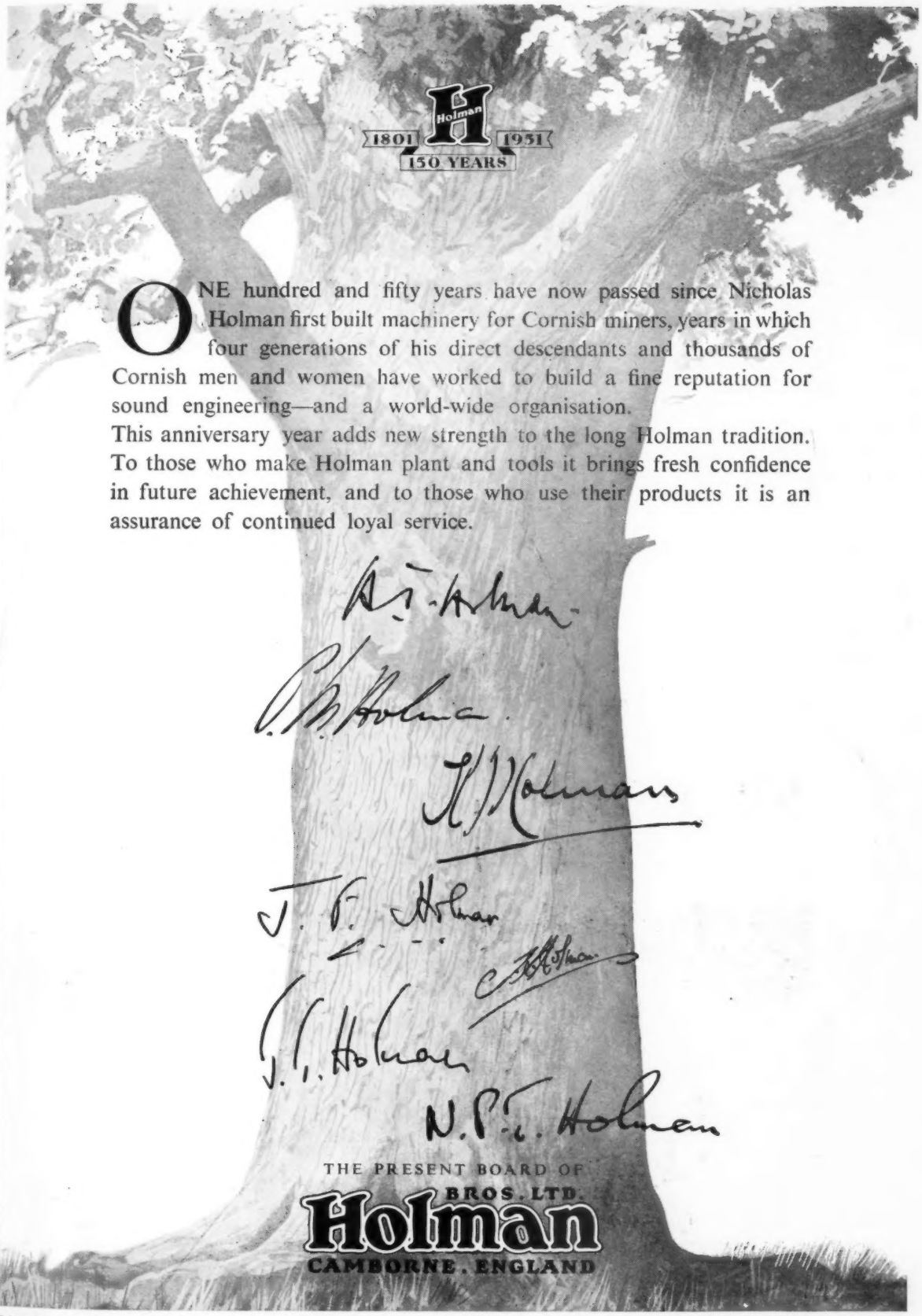
Y
Yorkshire Electric Transformer Co. Ltd. 1
Yorkshire Switchgear & Engineering Co. Ltd. 48



Generating Station Main Duplicate Bus Bar Switchgear consisting of twenty IV104 Metalclad Units for 6.6kV. service, short-circuit capacity 250 MVA. Solenoid closed, remotely operated from desk pattern Control Board and separate Relay and Instrument Board.

YORKSHIRE SWITCHGEAR
AND ENGINEERING COMPANY LIMITED
Telephone: 51030-8-9 **LEEDS** *Telegrams: "Controller"*
London Office & Showrooms: Grand Bldgs, Trafalgar Sq., W.C.2 Phone: Whi. 3530. Grams: Tramsuplim, Rand
ASSOCIATED WITH ELECTRO MECHANICAL MANUFACTURING CO., LTD., SCARBOROUG

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.
and Printed by W. & H. SMITH LTD., Evesham, Worcestershire. *January, 1951.*


Holman
1801
1951
150 YEARS
ONE hundred and fifty years have now passed since Nicholas Holman first built machinery for Cornish miners, years in which four generations of his direct descendants and thousands of Cornish men and women have worked to build a fine reputation for sound engineering—and a world-wide organisation.
This anniversary year adds new strength to the long Holman tradition. To those who make Holman plant and tools it brings fresh confidence in future achievement, and to those who use their products it is an assurance of continued loyal service.
THE PRESENT BOARD OF
BROS. LTD.
Holman
CAMBORNE . ENGLAND

Holman Bros. Ltd., Camborne, England, Phone: Camborne 2275 (7 lines), Grams: Airdrill, Camborne. Subsidiary Companies, Branches & Agencies throughout the World.

'ENGLISH ELECTRIC'

hydro-electric power

130 Megawatts from Sloy

The years of planning and labour which have gone to the realisation of the Loch Sloy scheme have had one fundamental object in view—the harnessing of Glen Sloy's 120-inch annual rainfall to drive four 'English Electric' hydro-electric generators delivering 130,000 kW of electric power.

The four 45,500 h.p. turbines with Francis-type runners are controlled by cylindrical balanced valves from a gross head of 920 ft. The 32,500 kW main alternators are coupled through 'English Electric' power transformers and oil-break switchgear to the grid at a pressure of 132 kV.

'English Electric' have played a large part in the development of Scotland's hydro-electric resources since the Galloway and Grampian projects, and are building equipment for several of the schemes which the coming years will see in being.

THE ENGLISH ELECTRIC COMPANY LIMITED

QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydraulic Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL